

**SPATIAL PATTERN AND TEMPORAL DYNAMICS OF NORTHERN
BOBWHITE ABUNDANCE AND AGRICULTURAL LAND USE, AND
POTENTIAL CAUSAL FACTORS**

A Dissertation

by

ATIYE ZEYNEP OKAY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of
DOCTOR OF PHILOSOPHY

December 2004

Major Subject: Urban and Regional Science

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ABSTRACT

Spatial Pattern and Temporal Dynamics of Northern Bobwhite Abundance and

Agricultural Land Use, and the Potential Causal Factors. (December 2004)

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There was a long-term decline in northern bobwhite (*Colinus virginianus*, NBW) abundance since the 1920s, based on the Christmas Bird Count (CBC) data, but with substantial spatial and temporal variations across its range. There were four recognizable periods in the spatial and temporal dynamics of NBW abundance between 1920 and 1990. Severe weather conditions and habitat loss due to land use change appeared to be the most important factors influencing the long-term trends and spatial patterns in NBW abundance.

A spatial database of agricultural land use was developed based on the Census of Agriculture to evaluate the spatial patterns of land use variables over NBW range from 1920 to 1997. The results showed dramatic changes in land use over the period and the influence of socio-economic events, natural disasters and federal agricultural policies on the dynamics of land use pattern, and potential implications to NBW abundance were identified. Replacement of less intensive agriculture with intensive monoculture production and mechanization coincided with World War I, and the post-war collapse in agriculture and the economy, partly associated with the Dust Bowl, enhanced this trend.

Monoculture production and clean farming practices were further intensified during World War II and the years following the war. These land use changes had overall negative effects on NBW habitat.

Analysis of the changes in spatial pattern of NBW abundance in the Great Plains region during the severe drought of the 1950s showed a significant decline in NBW abundance during the drought and a contraction of the NBW range at its western edge. The post-drought recovery exhibited spatial patterns significantly different from the pre-drought ones. These findings suggested that severe drought caused short-term changes in regional distribution of NBW and range contraction, as well as long-lasting, large-scale changes in spatial distribution of NBW abundance.

This study provides scientific basis for landscape planning and management. Evaluating the spatial pattern and temporal dynamics of certain wildlife species at large scales over long-term periods, and identifying potential causal factors are key strategies for implementing innovative and sustainable approaches to planning and policy. Such strategies will have a significant impact on future landscape and wildlife species.

DEDICATION

To

Berk, Ertan & my parents

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CHAPTER I

INTRODUCTION

As human beings, we revere the urban open spaces that define the landscape and natural heritage of the nation. However, we are deeply concern about rapid loss of open spaces to sprawling urban and agricultural development. The loss of open spaces and landscapes will increase as the nation's population continues to grow and agricultural acreages increases. The conversion of these areas to towns and farms results in the loss of invaluable wildlife species and fewer opportunities for us to enjoy the outdoors. In order to meet the needs of people and protect wildlife species, we need to make the acquisition of sustainable wildlife habitat and protection of ecologically sensitive urban areas a top priority.

In other words, we have to prepare regional planning that focusing on preserving and incorporating, in a continuous, urban open-space network, unique habitats and those habitats limited to the region. In this sense, urban planners, landscape architects, landscape ecologists, wildlife biologists and land use developers should work together to create sustainable wildlife habitat and significant natural areas. A broad conservation strategy for urban and urbanizing areas should strive to maintain diversity in regional wildlife species while also accommodating human needs and desires.

In this study, my goal was to provide scientific support for landscape planning and the field of science in landscape ecology. This research will suggest an application of interdisciplinary study between scientists and planners that can result in sustainable wildlife management and landscape preservation. Evaluating the spatial pattern and

temporal dynamics of certain wildlife species on a large scale over a long time period and identifying potential causing factors are key to opening to new ways of developing innovative and sustainable approaches to planning and policy, which have the most significant impact on future landscape and wildlife species.

BACKGROUND

As a widely distributed and popular game species, northern bobwhites (*Colinus virginianus*, NBW) have been extensively studied since at the earlier 20th century. Despite intensive studies and management efforts, steady declines in NBW abundance during the recent decades have been documented (Droege and Sauer 1990, Brennan 1991, Church et al. 1993, Brady et al. 1993, Peterson et al. 2002). Relatively few studies have been conducted to examine trends in NBW abundance throughout its range and most of these studies were based on the North American Breeding Bird Survey (BBS), which was initiated in 1966 (Droege 1990, Church et al. 1993, Brady et al. 1998). A few studies based on the National Audubon Society's Christmas Bird Count (CBC, Butcher 1990) also focused on the 1960s and later (Brennan 1991, Sauer et al. 1996), although the CBC began in 1900. Some early researchers argued that regional declines in NBW abundance started sometime between 1877 and 1905 (Leopold 1931, Stoddard 1931, Errington and Hamerstrom 1936). There is a need to evaluate the trends and spatial patterns in NBW abundance prior to the 1960s and to explore the causal factor shaping the patterns and dynamics in NBW abundance.

Possible factors influencing the long-term trends in NBW abundance include habitat loss, fragmentation, and conversion resulting from changes in land use (Klimstra

1982, Brennan 1991, Church and Taylor 1992, Brady et al. 1998, Peterson et al. 2002). Several studies assessed how regional or range-wide trends in NBW abundance were affected by the changes in land use and land cover (Vance 1976, Roseberry et al 1979, Roseberry and Klimstra 1984, Brady et al. 1993, Roseberry and Sudkamp 1998, Brady et al. 1998). However, these studies were mostly performed at coarse spatial scales such as state or physiographic region. Therefore, they presented a limited amount of information related to trends in NBW abundance as correlated with long-term changes in land use and landscape characteristics (Peterson et al. 2002). Peterson et al. (2002) examined the effects of long-term land use changes on NBW abundance at a finer scale based on county-level data from the Census of Agriculture (USDA-NASS 2000), but only since 1978 because of the limitation of data availability (electronic data available only for 1978-1997). In order to explore historical patterns of land use and their influence on NBW abundance, an electronic database for the historical land use data must be developed.

The decline in NBW abundance has been attributed primarily to habitat loss from changing land use in agriculture and forestry as well as increasing urbanization (Brennan 1994, Lee and Brennan 1994). However, alternative factors are potentially significant for regulating NBW populations. Extreme weather conditions such as drought or severe winters have a detrimental impact on NBW abundance and its habitats (Giuliano and Lutz 1993, Giuliano et al. 1999, Lusk et al. 2002). Extensive drought events can potentially have a significant impact on regional patterns of NBW abundance, especially in semi-arid regions. Although many local-scale studies have examined the effect of drought on NBW, few studies have examined regional-scale patterns of NBW response to

drought in a spatially explicit manner. Thus an interesting research question is whether severe drought results in range contraction along the western edge of the NBW range. Some scientists (Schorger 1946, Bolgiano 2000) speculated that widespread drought might reduce an entire quail population and compel them to migrate hundreds of miles to other places where they could survive. The severe droughts that occurred in the Great Plains during the 1930s and 1950s had a significant impact on both agriculture and many wildlife species (Wilhite 2003), and may offer a good test case for such hypotheses.

RESEARCH OBJECTIVES

This research effort was a step towards obtaining better knowledge of the historical pattern and dynamics of NBW abundance and related agricultural land use activities throughout the NBW range, and gaining insights into the causal factors and mechanisms for these patterns and dynamics. The overall objective was to examine the spatial patterns of NBW abundance over time and the climatic and land use factors controlling the patterns, and the socio-economic and policy factors influencing the land use patterns. There were three specific research objectives of this study:

- 1) Evaluate the spatial patterns of NBW abundance throughout its range and their changes between 1920 and 1990, and explore possible causes of these patterns and changes.
- 2) Develop a database of historical agricultural land use based on the Census of Agriculture, evaluate spatial patterns of land use variables abundance throughout the range of NBW and their changes from 1920 to 1997, and explore possible causes of these patterns and changes.

- 3) Examine the spatial pattern of NBW abundance in the Great Plains region before, during and after the severe drought of the 1950s and test the hypothesis that the NBW range contraction occurred during severe drought along the western edge of the range.

ORGANIZATION OF DISSERTATION

This dissertation is organized in five chapters. A brief introduction of the dissertation, including the general background and research objectives, is presented in Chapter I. A study on the spatial and temporal patterns of NBW abundance from 1920 to 1990, the spatial trend of changes in NBW abundance between decades, and the possible causes of the changes and decline in NBW abundance are presented in Chapter II. Chapter III examines the spatial and temporal dynamics of land use pattern including that of individual land use and crop variables between 1920 and 1997 within the range of NBW, the influence of physical and social changes and agricultural policies on the dynamics of land use pattern, and potential implications to NBW. In Chapter IV, the longitudinal pattern of NBW abundance in the Great Plains before, during, and after the severe drought of the 1950s is examined to evaluate the short-term and long-term influence of drought on the spatial distribution of NBW and test the hypothesis that the severe drought resulted in a contraction of the NBW range at its western edge. A summary of the results of the studies discussed in Chapters II-IV is presented in Chapter V.

CHAPTER II

LONG-TERM ASSESSMENT OF RANGE-WIDE TRENDS IN NORTHERN BOBWHITE ABUNDANCE

INTRODUCTION

One of the primary objectives of ecology is to understand how populations are spatially structured. The best way of looking at this issue is to describe how species' abundance varies temporarily and spatially and then identify the mechanisms that cause these variations. Assessing long-term changes at broad scale is essential for management and so conservation planners can explain where and how certain species' abundance is increasing and decreasing.

As we begin the 21st century, like many other grassland breeding birds (Askins 1993, Peterjohn and Sauer 1999, Vickery et al. 1999, Murphy 2003), northern bobwhite (*Colinus virginianus*, NBW) abundance has been declining throughout most of this species' geographic range for decades (Droege and Sauer 1990, Brennan 1991, Church et al. 1993, Sauer et al. 1996, Brady et al. 1998, Peterson et al. 2002). Although Leopold (1931) and Lehmann (1937) argued that the initial decline in bobwhite abundance started somewhere around the 1880's, these declines appear to have become more dramatic in recent years (Church et al. 1993, Brennan 1993).

According to Dimmick et al. (2002) argued that bobwhites might face a threat of extinction by the end of this century unless considerable management effort is directed toward reversing this situation. Roseberry (2000:244) also concluded that "...in the face

of an ever-expanding human presence on the landscape, only a few wildlife species will ultimately thrive, and bobwhite will probably not be one of them”.

Recent studies using North American Breeding Bird Survey (BBS; Droege 1990) and National Audubon Society's Christmas Bird Count (CBC; Butcher 1990) data demonstrated that a broad scale decline in bobwhite abundance occurred in 77 % of the states within their geographic range since at least the 1960's (Brennan 1991). Long-term (1966-1993) trends from BBS data showed that the decline rate for the continental United States was about 2.8 % (Thogmartin 2002).

The downward trend in bobwhite abundance has been experienced not only at continental but also at the regional and state levels (Brennan 1994). The rate of decline varies among portions of bobwhite range. Droege and Sauer (1990) estimated that the rate of decline from 1966 to 1989 was about 1.8 % for the entire United States, 3.3 % and 0.7 % in the eastern and central portions of the United States, respectively. Since the southeast has traditionally been center of bobwhite abundance and management (Brennan 1993), the greatest decline has occurred in this region (Lee and Brennan 1994). Moreover, the annual rate of decline for the southeastern United States has accelerated from 1.7 % from 1966 to 1979 to 5.3 % from 1980 to 1999 (Sauer et al. 2000).

Research related to the NBW decline did not receive much attention until 1930s (Rosene 1969), although many wildlife scientists and hunters were aware of it previously. The decrease in bobwhite numbers typically was attributed to overshooting until the 1930's. Many hunters and managers believed that limiting the hunting season length and/or the number of bobwhites in the daily bags would reverse the decline in abundance

(Rosene 1969). They were incorrect. Despite significant restrictions on bag limits and season length bobwhite abundance continued to decline.

Herbert L. Stoddard (1931), Aldo Leopold (1937), and Paul Errington (1945) are recognized as important pioneers in NBW study. They provided initial theoretical and methodological studies on bobwhite life history and ecology (Guthery 2002). Since then much research has been devoted to bobwhite species (Rosene 1969, Lehmann 1984, Roseberry and Klimstra 1984, Hernandez et al. 2002). More than 3000 articles were published by wildlife scientists and managers by 1990 (Scott 1985, Church and Taylor 1992).

Many more have been published since. These articles focused on the bobwhite biology (Curtis et al. 1993, Townsend et al. 2003), model habitat relationships (Guthery 1997, Roseberry and Sudkamp 1998, Guthery et al. 2000a), diseases and parasites (Parmalee 1952, Davidson et al. 1982, Williams et al. 1997), physiology and genetics (Mueller and Dabbert 2002, Schable et al. 2004), and certain management treatments such as prescribed burning (Speake 1966, Carter et al. 2002), grazing (Baker and Guthery 1990, Ribic 1998, Stewart et al. 2004), and food and feeding habits (Baldwin and Handley 1946, Laessle and Frye 1956, Brennan and Hurst 1995).

Previous Evaluations of Bobwhite Trends

Historically, trends in NBW abundance have been examined at various spatial and temporal scales in different studies with little explicit assessment of the influence of spatial and temporal scaling. For example, Roseberry and Klimstra's (1984) conducted intensive long-term research from 1953 through 1979 on the ecology and population

dynamics of a bobwhite population on a privately owned farmland located northeast of Carbondale, Illinois. They emphasized population dynamics and factors affecting short-term fluctuations and long-term trends in NBW abundance.

Lee and Brennan (1994) examined fluctuations in NBW abundance from 1955 through 1992 in the Copiah County Wildlife Management Area in southern Mississippi. Brady et al. (1993) also attempted to examine the trends of NBW abundance in Kansas between 1966 and 1991 by using both Rural Mail Carrier Survey reports and BBS data.

Likewise, using similar approaches a number of other studies (Errington and Hamerstrom 1936, Errington 1945, Thogmartin 2002) have been conducted for most parts of the bobwhite range for decades to estimate the distribution, abundance and population trends of the species. These efforts were invaluable; however, they presented limited amount of information related the NBW population dynamics because they were performed almost exclusively at very fine scale such as ranches, state research stations, or quail management preserves.

Few studies have addressed both range-wide and long-term changes in NBW numbers. Droege and Sauer (1990) examined the range-wide trends in NBW abundance of a long period (1966-1988) using BBS data. They also attempted to evaluate the dynamics in bobwhite abundance based on physiographic regions within each state and region of the United States. Similarly, Church et al. (1993) used BBS data to estimate long-term (1966-1991) and short-term (1982-1991) changes in NBW distribution and abundance throughout states and physiographic regions. Brady et al. (1998) also examined the population trends of bobwhite by using BBS data from 1970 through 1994.

Finally, Peterson et al. (2002) presented an analysis of spatial and temporal patterns of population trends of NBW abundance from BBS data for 1978, 1987, and 1997.

Droege and Sauer (1990), Church et al. (1993), Brady et al. (1998) and Peterson et al. (2002) all attempted to provide information about the distribution, relative abundance and trends of NBW since 1966 throughout their geographic range. Since these studies were based on the BBS, which was initiated in 1966 and developed complete coverage route in 1968 (Droege et al. 1990, Church et al. 1993, Brady et al. 1998), trends in NBW abundance prior to the 1960s have yet to be examined.

Although the CBC began in 1900, bobwhite studies based on these data did not make use of information collected before about 1960 (e.g., Brennan 1991, Sauer et al. 1996). Despite the fact that the CBC was not as well standardized as BBS, particularly during early years, its much longer duration could shed new light on historical bobwhite abundance and trends. Leopold (1931), Stoddard (1931), and Errington and Hamerstrom (1936) all agreed that the long-term, broad-scale decline in bobwhite abundance started in the early 20th century. Therefore, it seems essential to evaluate such trends prior to the 1960s. The primary objective of this chapter is to provide insight into the broad temporal and spatial patterns of NBW abundance from 1920 to 1990 throughout their range based on CBC data and specify the possible reasons causing this species' population decline.

METHODS

Data Description

Information on the status of avian species is obtained from CBC and BBS, as well as from surveys conducted by many state wildlife agencies. These surveys are conducted

annually at numerous sites across North America. Despite differences in the ways the data are gathered, these data sets provide detailed information about the status and the distribution of bird populations throughout the continental United States and Canada (Droege and Sauer 1990).

The CBC is considered as “the oldest and largest wildlife survey in the world” (Butcher 1990:5). Since the CBC enumerates avian abundance during the winter, it is an important supplement to the BBS (Robbins et al. 1986). Thus, the CBC also provides a different perspective on many species’ distribution and trends from that provided by the BBS.

The CBC program was initiated in 1900 and is coordinated by the National Audubon Society. The survey is conducted by over 40,000 participants who visit a series of designated circles that are 15 miles (24 kilometer) in diameter within 2 weeks of Christmas to collect data on bird populations (Butcher 1990). These data have been widely used to estimate population trends at various spatial scales, demonstrate temporal dynamics in these trends, and exhibit spatial patterns in the distributions and relative abundances of birds. The results of the counts are compiled into a database, which represents over a century of data on the trends of bird populations all across the North America.

Data Analysis

CBC data from 1920 through 1990 were selected to evaluate the relative abundance of NBW within their geographic range. All processes such as number of observations and observers, coordinates, names and identification numbers of circles,

weather conditions, and total efforts, measured in party-hours and party-miles, spent for a particular circle each year were analyzed with the statistical software SAS (Version 8.01; SAS Institute Inc., Cary, NC).

Since observer effort influences the number of birds counted in the circles, particularly for the species such as the NBW that usually occur in high densities, it is critical to correct counts for these influences when using CBC data (Butcher 1990). Butcher and McCulloch (1990) proposed a method using nonlinear models to develop standardized population indices based on effort in party-hours or party-miles. They defined a party as “a group of birders traveling together and remaining within sight and sound of each other”, party-miles as “the number of miles traveled by all parties on a CBC” and party-hours as “the number of hours spent looking for birds” (Butcher and McCulloch 1990: 121).

The relationship between count and effort was modeled using nonlinear regression: $CT = e^A(X)^B(YR)^C$, where CT = count, A is the intercept on the original scale, X = effort measured by party-hours or party-miles, B is the change in slope on the original scale, YR = year and C is the slope on the original scale for the year effect. The best estimate of B (B) for bobwhite species was estimated using the nonlinear regression; the standardized count (SCT), based on a standard value (SV) for effort was also estimated $SCT = CT(SV/X)^B$. This method is superior to the log-log regression models that require addition of an arbitrary constant (Butcher and McCulloch 1990).

Although the CBC started collecting data at the beginning of the 20th century, most of the observer effort data are not available for the early decades. These data in both party-hours and party-miles were recorded in CBC database since about 1945,

although some of the years between 1938 and 1944 include either party-hours or party-miles or both. There were no effort data associated with counts made between 1912 and 1916. Only party hours were recorded between 1900 and 1911 whereas party-miles were noted mostly from 1917 through 1937. Since party-miles are available for a longer period and are likely to be more highly correlated with NBW species during December than party-hours, nonlinear models using party-miles were developed to standardize the bobwhite count data.

NBW range was delineated using ArcView GIS based on the circles where bobwhites have been observed at least once. All areas within 15 miles (24 km)) of these circles within the continental United States were used to define the range of NBW. In order to develop a standardized, representative population index of abundance from 1920 through 1990, and given the stochastic nature of NBW abundance, a 5-year mean value centered on each 10th year was used and only circles surveyed in at least 3 of the 5 years were included in the analysis. These circle data then were interpolated to continuous grids of bobwhite abundance with $2 \times 2 \text{ km}^2$ resolution using the inverse distance weight (IDW) interpolation method in ArcView Spatial Analyst (ESRI 1998). Additionally, each 10 year interpolated bobwhite population index was subtracted subsequently from the previous index each to explore how trends of NBW abundance varied among decades.

RESULTS

This study revealed that there has been a significant range wide decline in NBW abundance (Fig. 2.1) over the 70-year period (1920-1990). NBWs were abundant in most portions of the species' range in 1920s (Fig. 2.2A). At the range wide scale, bobwhites

had become far less abundance by 1950 (Fig. 2.2A-D). Range-wide declines continued at a decreased rate from 1960 through 1990 (Fig. 2.2E-H).

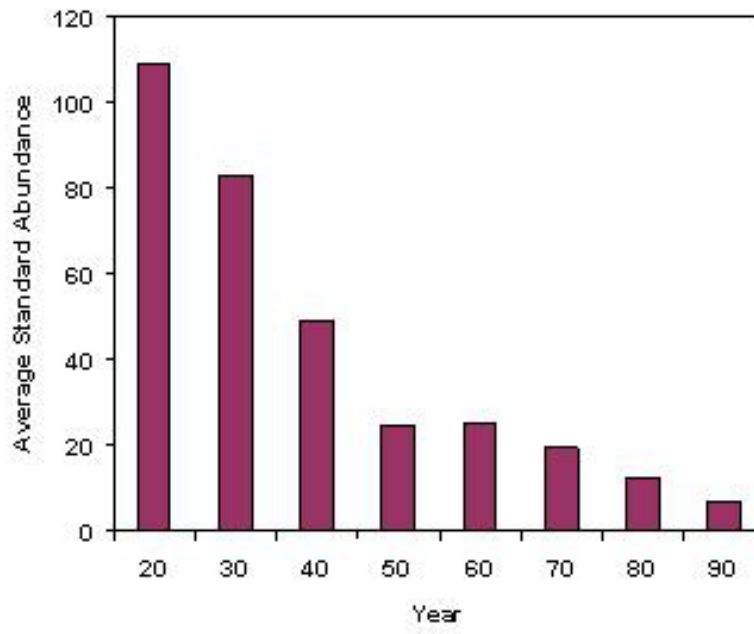


Fig.2.1. Range-wide population trends in NBW abundance based on Christmas Bird Count (CBC) data

Bobwhite abundance increased between 1920 and 1930 in most of Colorado, Wyoming, and Nebraska (Fig. 2.3A). Similarly, bobwhite abundance increased most of South Carolina and some parts of Georgia, North Carolina, and Tennessee. Other regions of increased abundance occurred in southern Michigan, Indiana, Ohio, northern Kentucky, Illinois, Iowa and Missouri, and eastern Kansas, and central Oklahoma (Fig. 2.3A). Abundance decreased between the 10 year period surrounding 1920 and 1930 for most of the remainder of the United States.

The region noted for increases in bobwhite abundance during the previous decade typically declined dramatically between 1930 and 1940 (Fig. 2.3B). Bobwhite abundance

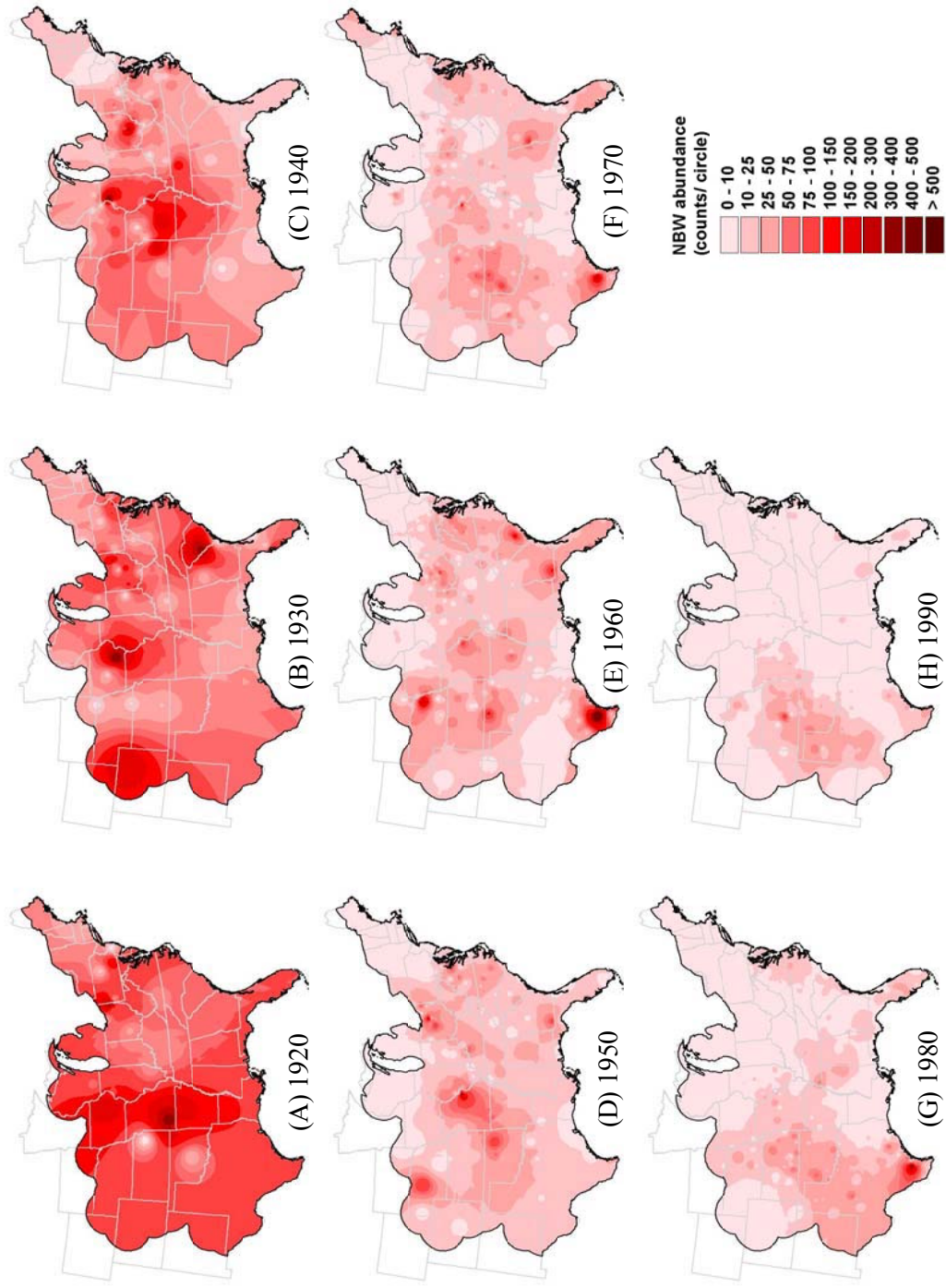


Fig. 2.2. Northern bobwhite abundance (5-year mean, Christmas Bird Count), 1920-1990

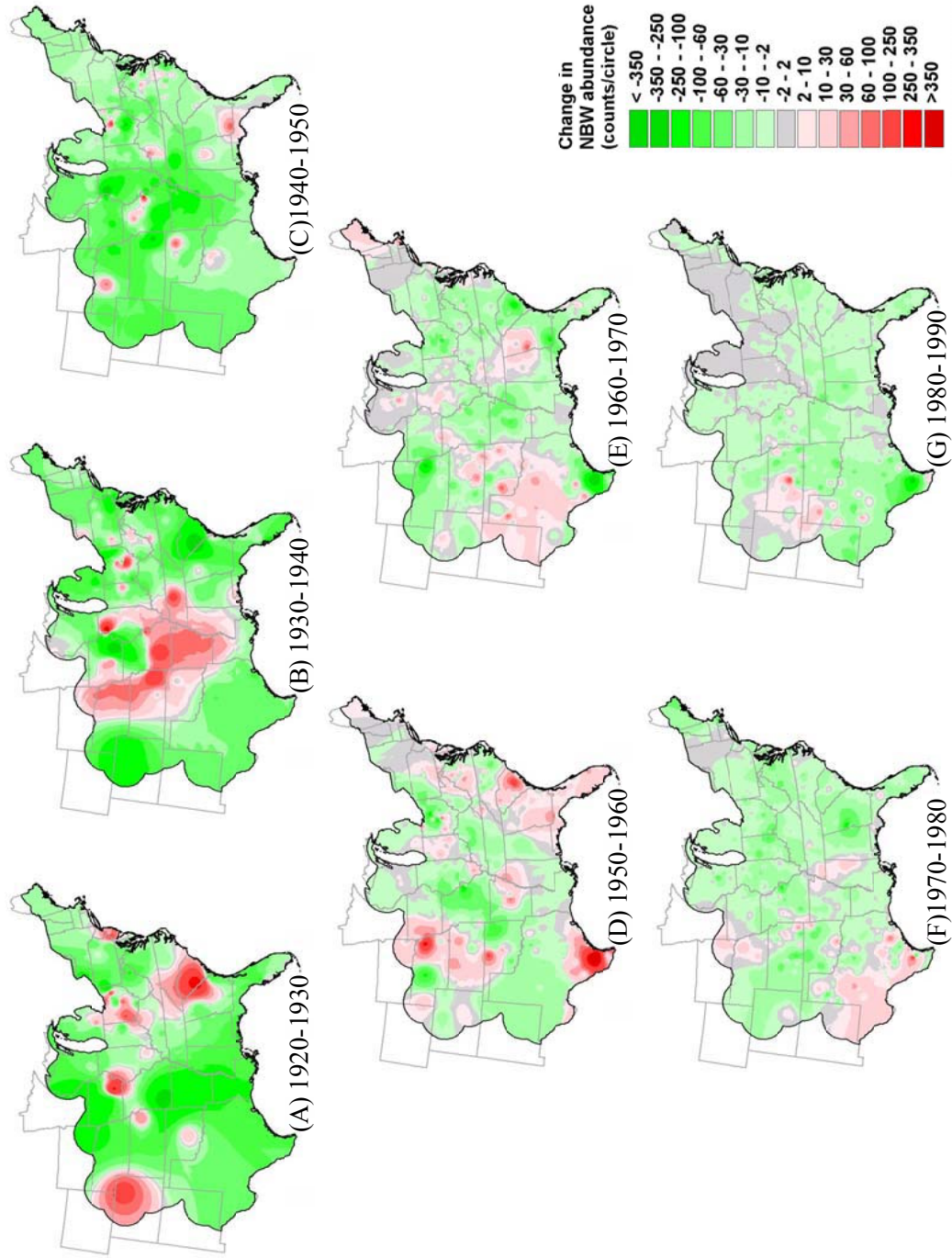


Fig. 2.3. Changes in northern bobwhite abundance from 1920 to 1990

increases, however, in the central states stretching from Missouri, Arkansas, Tennessee and Illinois east through most of Kansas, Nebraska, and South Dakota and south Louisiana, and Mississippi. Slight increases were noted in portions of Indiana, West Virginia, Pennsylvania, and Ohio (Fig. 2.3B). The remainder of the United States was characterized by decreasing bobwhite abundance.

The period from 1940 to 1950 was characterized by marked decrease in bobwhite abundance (Fig. 2.3C). In fact, there were no regions of the United States of characterized by marked, broad scale in NBW numbers. However, some isolated increases occurred in central Nebraska, Kentucky, Alabama, and small parts of western Oklahoma and Texas, Missouri, Ohio, North Carolina, and Virginia (Fig. 2.3C).

The overall pattern associated with trends in NBW abundance differed considerably from 1950 to 1960 than during previous decades (Fig. 2.3D). The only areas characterized by marked increases in bobwhite numbers occurred in southern Texas, eastern Nebraska, north-central Oklahoma, and southeastern South Carolina. Marked decreases occurred from eastern Illinois through northeastern Oklahoma and in western Nebraska (Fig. 2.3D). Most of the remainder of the United States was characterized by slight increases and decreases in bobwhite abundance extending across state boundaries.

In contrast, the marked gains that occurred in south Texas, eastern Nebraska, north-central Oklahoma, and southeastern South Carolina from 1950 to 1960 were characterized by substantially decreased abundance from 1960 to 1970 (Fig. 2.3E). Major decreases also were observed in various portions of Georgia, Mississippi, Arkansas, and Iowa during this decade. Bobwhite abundance increased slightly in New Mexico, central

and eastern Texas, eastern Oklahoma and southeastern Kansas, and much portions of Alabama and Georgia (Fig. 2.3E).

The period from 1970 to 1980 was characterized by moderate declines in NBW abundance across most of this species' range (Fig. 2.3F). Slight gains were seen in South Dakota, north western Iowa, eastern Nebraska, western and southern Texas, southern New Mexico, northeastern Mississippi, and in small pockets in Oklahoma, Colorado, Kansas, Missouri, and elsewhere (Fig. 2.3F).

Although the species abundance stayed relatively stable in northeastern parts of the range between 1980 and 1990 (Fig. 2.2), the marked decline in NBW abundance occurred in south (Fig. 2.3G). Slight declines in bobwhite abundance occurred during this period across most of the remainder of this species' range with the exception of the region including the Texas and Oklahoma panhandles and eastern Kansas and western Colorado (Fig. 2.3G).

DISCUSSION

There had been an overall decline in the abundance of NBW at the range-wide scale since at least the 1920s (Fig. 2.1). However, the spatial pattern of the trends in abundance varied across decades over the species' range (Fig. 2.2A-G). There appeared to be four recognizable periods between 1920 and 1990 in the spatial and temporal dynamics of NBW abundance across its range: a substantial but spatially variable decline from 1920 to 1940, a spatially consistent decline throughout the range from 1940 to 1950, a relatively stable but spatially dynamic period from 1950 to 1970, and another marked decline from 1970 to 1990. The possible causes of the dynamics in the trends and spatial pattern were explored below based on reviews of the literature corresponding with the patterns shown in the results of this study. Severe weather conditions and habitat loss due to changing land use appeared to be the most important factors influencing the long-term trends and spatial patterns in NBW abundance.

1920-1940

Although NBW was abundant in most parts of its range around 1920, its overall abundance declined substantially, but with considerable spatial variation, from 1920 to 1940 (Fig. 2.2A-C). A significant decline was noted almost all over the NBW range except in most portions of Colorado, Wyoming, Georgia, South Carolina, North Carolina and Ohio between 1920 and 1930 (Fig. 2.3A). However, some of the regions which were characterized by decreases in NBW abundance during the previous decade showed significant increases between 1930 and 1940 (Fig. 2.3B).

In general, NBW abundance increases during relatively mild winters, and a series of favorable winters may result in eruptions in their abundance; in contrast, a prolonged harsh winter can devastate local abundance (Leopold 1931). According to Errington (1934), during the winter of 1929-30, deep snow in Wisconsin reduced the number of NBW; conversely, the mild winter of the following two years led to increased abundance. Scott (1940) believed that 83 % of the NBW in Wisconsin vanished during 1935 and 1936 due to bad weather.

The result of this study illustrated that there were significant increases in NBW abundance in the southern central portions of the NBW range between 1930 and 1940 (Fig. 2.3B). Severe weather and snow conditions generally demarcate the northern boundaries of the species range (Edminster 1954, Roseberry and Klimstra 1984). Edminster (1954) states that severe winters which occurred in the North between 1935-1936 devastated a majority of the NBW abundance and forced them to migrate to the South.

Winter losses, which take place particularly in the northern states of the species range such as Ohio, Wisconsin, Michigan, and Iowa (Baerg and Warren, 1949), are mostly related to starvation (Leopold 1933, Errington 1945, Kabat and Thompson 1963) associated with long durations of snow cover and freezing temperature (Errington and Hamerstrom 1936, Errington 1945). The winter in Iowa between 1935 and 1936 was so extreme that deep snow obscured NBW food and nesting cover. Rosene (1969) believed that NBW numbers were severely reduced that winter.

Drought might become a limiting factor for NBW survival and reproduction (Guthery et al 1988, Koerth and Guthery 1991, Giuliano and Lutz 1993). Errington

(1935) declared that the drought that occurred in southern Iowa in 1934 resulted in eradication of the entire year's hatch. According to Rosene (1969) the summer drought in the Midwest in 1934 critically depressed NBW production. Similarly, the drought period of the 1930s also caused poor NBW abundance in Missouri (Bennitt and Nagel 1937) and in Iowa (Errington 1935).

Habitat loss and fragmentation have become a growing concern for most wildlife species including NBW (Wilcove et al. 1986). Burger (2002) points to reductions in landscape heterogeneity, which decreases the percentage of usable spaces for NBW (Guthery 1997). Introduction of mechanization and artificial chemical fertilizer into farming practices since the beginning of the 20th century (Cochrane 1993) resulted in habitat loss for the NBW species. Farm sizes were enlarged accordingly to support enough equipment and apply new techniques (Goodrum 1949, Gardner 2002). The decline in NBW abundance in western Oklahoma from 1920 through 1935 was attributed to increases in machinery and acreage of agricultural farms (Duck and Fletcher 1943).

These extensive changes eradicated numerous weedy fencerows and small farms supplying the best nesting, brood rearing and protective cover for this species (Klimstra 1982). According to Stoddard (1931: 357) "not only are modern agriculture practices seriously curtailing the food supply of quail, but the recent tendency to clean up thickets, hedges and fence rows also serves both to expose the birds to attack by natural enemies and to isolate coveys in widely separated 'islands' of thicket cover, or even to extirpate the birds from great areas." Errington and Hamerstrom (1936) speculated that the probable causes for the NBW abundance decline in Iowa around 1930s were habitat loss and fragmentation. Kabat and Thompson (1963) had the same conclusion in that the loss

of hedgerow cover in Wisconsin resulted in dramatic declines in NBW abundance from 1937 to 1962.

1940-1950

Dramatic, spatially consistent reductions in NBW abundance were noted from 1940 to 1950. There were almost no regions in the NBW range characterized by marked, broad scale increases in NBW numbers (Fig. 2.3C). The decline in NBW abundance could be partially attributed to drought that occurred during this period. Jackson (1950) found that severe drought observed in north-central Texas in 1948 depleted egg production that caused reductions in abundance. Jackson (1962) also concluded that drought periods lasting several years in the Rolling Plains of Texas, combined with livestock grazing practices and plant succession contribute to most of the depletion in NBW abundance.

NBW abundance can be as sensitive to rain and precipitation as to freezing temperature and drought (Stoddard 1931). Abundance might increase or decrease as a result of intensity of rainfall. Stoddard (1931) and Rosene (1969), based on their studies in the Southeast, found high and low NBW abundance after the spring and summer rainfall. Excessive spring rainfall may wash away NBW nests and reduce breeding effort (Guthery et al. 2000b). Chicks are especially vulnerable to cold and rainy weather (Edminster 1954). A heavy rain in 1953 lasted about a week in South Carolina, resulting in a decline in NBW abundance by destroying most of the nests and causing an increase in chick mortality (Rosene 1969).

Many wildlife scientists also believed that severe winters that occurred during this decade resulted in a decline in NBW abundance. Kozicky and Hendrickson (1952) noted that the unfavorable winter conditions in Iowa from 1935 to 1951 led to an 87.8% reduction in NBW. Rosene (1969) believed that an unexpected drop in temperature and a snowstorm in 1951 in Kentucky reduced the number of NBW suddenly.

NBW abundance was impacted by both the quality and the quantity of food and cover. Providing sufficient food supply and cover is not exclusively adequate to increase NBW abundance. The quality of both is also critical for survival and growth. “The deficiencies in quality and quantity of cover” in the southeastern part of the range since 1940 caused severe devastation: NBW abundance has shown a decreasing trend since then (Rosene Jr. 1956:126). Baerg and Warren (1949) believed that one of the reasons for NBW abundance decline in Arkansas from 1942 to 1946 was unfavorable habitat. The number of NBW was reduced significantly even though rice and soybean were abundant in the surroundings. Wet ground also created damaging effects on NBW’s nest cover.

1950-1970

The abundance of NBW remained relatively stable between 1950 and 1970 and the spatial distribution of abundance varied in each decade in many parts of the range (Fig. 2.3D.E). Major increases were observed, mainly in the eastern and western parts of the range and South Texas from 1950 to 1960 (Fig. 2.3D). However, the increases in NBW abundance were mostly noted in western parts of the range from 1970 to 1980 (Fig. 2.3E).

Significant increases in NBW abundance were noted in certain portions of the range between 1930 and 1960 (Fig. 2.3B-D). Subsequent to World Wars I and II, hundreds of thousands of farms were abandoned, mostly in the Great Plains and southern parts of the United States (Ward 1946, Bowden 1977, Alig et al. 2003). The increase in NBW might be attributed to farm abandonment during this period. Even though a severe drought was experienced in Oklahoma during the 1930s, Duck and Fletcher (1943) observed an increase in NBW abundance in the western parts of the state around 1935 due to the abandonment of many farms throughout this decade. In a similar way, once a 250,000-acre land in Savannah River Plant, South Carolina, was purchased by the University of Georgia, the farms within the site were abandoned from 1952 to 1959. The number of NBW was double that of the surrounding area during that same period (Golley 1962).

1970-1990

Another widespread decline in NBW abundance occurred between 1970 and 1990 (Fig. 2.3F,G). The decline in NBW abundance was observed in almost every part of the range except portions of the Texas and Oklahoma panhandle from 1970 to 1980 (Fig. 2.3F). The only increase in NBW abundance from 1980 to 1990 was noted in the area of the Texas panhandle, eastern Kansas, and western Colorado (Fig. 2.3G).

Edwards (1972) suggested that a severe winter depressed NBW abundance dramatically in Illinois in the late 1970s. Robins et al. (1986) also stated that NBW abundance in the Ohio Valley and the Middle Atlantic states also declined very severely from 1976 to 1978 because of cold winters. Even though a considerable loss in

abundance was experienced in states in the Great Lakes, Northeastern and Southeastern regions, a substantial boost was observed in the Southwestern states especially in Texas during this period (Fig. 2.3F).

Changing practices in agriculture and silviculture that emphasized maximum food and fiber production had generally reduced quality and heterogeneity of habitat for wildlife (Exum et al 1982, Fies et al. 1992). Speake (1966:19) stated that “changing land use has been responsible for a general scarcity of good habitat for bobwhite...in Alabama Piedmont. Since the 1930s much of the former agricultural land of this region has been changed from cotton to corn production to planted pine or allowed to revert to forest. These young planted or natural pine forests became very poor quail habitat when the canopies closed.” According to Dimmick (1992), the main reason for the NBW decrease at Ames Plantation in western Tennessee from 1966 through 1991 was the replacement of idle farms with soybean production.

CONCLUSIONS

There has been a long-term decline in NBW abundance over most of its range despite the fact that it is the most intensively studied and managed species in North America (Church and Taylor 1992). By using data from CBC, range-wide changes in NBW abundance were evaluated from 1920 through 1990. The results illustrated that overall NBW abundance has been declining significantly over the past 70-year period but with considerable spatial variations.

Although NBW was generally abundant in most parts of its range around 1920, a substantial decline, but with considerable spatial variation, in NBW abundance occurred

between 1920 and 1940. A drastic, spatially consistent reduction in NBW abundance across the range was noted from 1940 to 1950. Between 1950 and 1970, the overall NBW abundance remained relatively stable but spatially dynamic. It was followed by another marked range-wide decline from 1979 to 1990 that reduced NBW abundance to very low levels over its range, except for parts of the western portion of the range.

The literature that documented historical trends in NBW dynamics and their causes at various regions and scales generally corroborated with the results in this study and suggested that severe weather conditions and habitat loss due to land use change appeared to be the most important factors influencing the long-term trends and spatial patterns in NBW abundance. NBW abundance is subject to dramatic fluctuations in response to weather conditions. It could increase during relatively mild winters, and a series of mild winters would allow NBW to become widely distributed. Conversely, prolonged snow cover and below-normal temperature could decimate NBW, while several severe winters in succession could result in its virtual disappearance from certain portions of its range.

Similarly, excessive drought or rain might devastate NBW to the same degree. In addition to weather conditions, changes in land use over the decades eliminated less intensive agriculture that was characterized with small fields combined with various crops and arrangements of hedgerows and brushy fences, which produced good NBW habitat. As a result, large-scale habitat loss and deterioration, due to large-scale land use changes, intensive monoculture practices in agriculture, and forestry, likely contributed to the decline in NBW abundance.

CHAPTER III

EVALUATION OF SPATIAL PATTERN AND TEMPORAL DYNAMICS OF LAND USE FROM 1920 TO 1997 OVER NORTHERN BOBWHITE RANGE

INTRODUCTION

There has been a widespread decline in northern bobwhite (*Colinus virginianus*, NBW) abundance for at least several decades (Brennan 1991, 1993; Church et al. 1993, Brady 1998). The decline of the NBW has been attributed to a variety of factors including fire ants (Brennan 1993, Brennan 1999, Mueller 1999), increased predation (Stoddard 1931, Errington 1934, Jackson 1947, Rollins and Carroll 2001), and increased use of pesticides (Brennan 1991). Although these factors may play a role at a local scale (Hurst et al. 1996), changes in land use practices resulting in fragmentation and habitat loss are most likely the causes of a broad scale decline in NBW abundance (Crow 1989, Brennan 1991, 1993; Church and Taylor, 1992, Brady et al. 1998). Clean farming and intensive monoculture practices in agriculture (Vance 1976, Exum et al. 1982, Burger 2002) and forestry (Brennan 1991, Burger 2002) are considered two important causes of widespread habitat loss and reduced habitat diversity (Brennan 1991, 1994).

Several studies assessed how trends in NBW abundance were affected by changes in land use and habitat at the local scale (Vance 1976, Roseberry et al. 1979, Roseberry and Klimstra 1984), whereas few of them attempted to address this relationship at physiographic region and range wide spatial scales (Brady et al. 1993, Roseberry and Sudkamp 1998, Brady et al. 1998). Since these studies were mostly conducted at very coarse scales, they presented a limited amount of information related to trends in NBW

abundance as correlated with long-term changes in land use and landscape characteristics (Peterson et al. 2002).

Trends in NBW abundance are spatially complex due to interactions among spatially patterned aspects of the biophysical environment and human-induced disturbances. Examining the trends in abundance particularly at the state level may not be appropriate because there is little relationship between NBW populations and political boundaries of the state lines. Since physiographic regions are not fine enough to characterize natural ecological divisions related to NBW, limiting analysis to physiographic regions might also obscure important spatial patterns, hindering our understanding of spatial scaling inherent to both the estimation of NBW abundance and the evaluation of associated trends in abundance (Peterson et al. 2002).

In their analysis, Peterson et al. (2002) attempted to explain how long-term changes in landscape characteristics might influence trends in NBW abundance at broad spatial scales. Unlike other studies, they used county-level land use data from the U.S. Census of Agriculture (COA) for 1978, 1987, and 1997. However, since the county-level land use statistics were only available electronically for 1978, 1987, and 1997, they could not examine the years prior to 1978.

An evaluation of the previous years is critical to the understanding of how land use and crop varieties have been changed and the influence these changes have had on trends of NBW abundance. The objective of this chapter is to elucidate the spatial and temporal patterns of the changes in land use and crop varieties across the NBW range between 1920 and 1997, the effects of federal policies and regulations on these changes, and the influence of these changes on the population trends of NBW.

METHODS

Data Development

The Census of Agriculture provides comprehensive statistics at the county level regarding land use and acreage of various crops, type of agricultural operation, production and operators (USDA-NASS 1997). The first agricultural census was taken in 1840 with the Sixth Decennial Census of Population and was taken every 10 years from 1850 to 1920. Beginning in 1925, the Census of Agriculture became a separate entity and was taken every 5 years through 1950. Detailed land use information also was added to the census in 1925. The Census of Agriculture became separate from the decennial censuses after 1950 and was taken for all years ending in “4” and “9” between 1954 and 1974, for 1978 and the years ending in “2” or “7” since 1982. County-level statistics for the Census of Agriculture are available in digital form for the years 1982, 1987, 1992, and 1997, but only in printed form for censuses conducted prior to 1982.

For this study, county-level statistics related to land use and crop varieties were extracted from the Census of Agriculture taken in 1920, 1930, 1940, 1954, 1964, 1978, 1987, and 1997. Digital data for 1978, 1987, and 1997 were acquired from the U.S. Census of Bureau (1997). Since statistics prior to 1978 are only available in printed form, the digital data related to land use and relevant crop acreages were manually digitized and proof checked based on the printed publications of the Census of Agriculture for 1920, 1930, 1940, 1954 and 1964.

Land Use Data Organization and Analysis

All land use categories in the Census of Agriculture are organized under “land in farms” which is composed of cropland, pastureland, woodland, and other land. Each of these categories is further subdivided into various subclasses. The category “Land in farms” also includes lands in the Conservation Reserve Program (CRP) and Wetlands Reserve Program (WRP). Some of the land use classes are listed in more than one category. For instance, the class “Woodland pastured” is listed under the categories of “total woodland” and “total pastureland”.

The organization of land use data in this chapter was based on the categories used in the census of 1978, and those of 1987, and 1997, since they shared the same classification structure. The main land use categories identified in these decades (USDA-NASS 1997) are as follows:

Total cropland

Total cropland consists of three main subcategories: cropland harvested, cropland used only for pasture or grazing, and other cropland. Other cropland also comprises the acreages of cropland in cover crops, legumes, and soil improvement grasses, which were not harvested and not pastured, cropland on which all crops failed, cropland in cultivated summer fallow and idle cropland.

Total woodland

Total woodland includes the sum of acreages of woodland pastured and woodland not pastured.

Total pastureland

The acreage of total pastureland includes cropland used only for pasture or grazing, woodland pastured, and pastureland and rangeland other than cropland.

Other land

The two classes that make up the “other land” category are 1) pastureland and rangeland other than cropland and woodland pastured, and 2) the land in house lots, ponds, roads, wasteland, etc.

Because the 1964 census did not have the same categories as the later censuses, the relevant categories of cropland harvested, cropland used only for pasture, and other cropland were summed up to provide the acreage for total cropland. The category “cropland not harvested and not pastured” was referred to as “other cropland” in later census data. In a similar way, the acreage of “woodland pastured” was added to the acreage of “woodland not pastured” to calculate “total woodland.” Since total pastureland was not recorded as a separate land use class in the 1964 census, the categories “cropland used only for pasture or grazing,” “woodland pastured,” and “pastureland other than cropland and woodland pastured,” were coalesced to form the integral part of the total pastureland base. The acreages of “other pasture,” called “pastureland and rangeland other than cropland and woodland pastured” and the total acreages of the land designated for house lots, barn lots, lanes, roads, etc., were combined to create an “other land” category.

The land use classes and subclasses in the census of 1954 are assembled in a similar manner to the 1978, 1987, and 1997 censuses, so no additional arrangement was

necessary. However, the land use types in the 1940s were not sufficiently differentiated in the Census of Agriculture to facilitate reclassification based on the categories of 1978, 1987, and 1997. In the organization of the 1940s census, the total cropland category was made by integrating cropland harvested, cropland failed, plowable pasture, and cropland lying idle or in summer fallow. The sum of the acreage of cropland failed and cropland lying idle or in summer fallow made up the “other land” category, whereas plowable pasture was renamed as the category “cropland used only for pasture” in the later censuses. The “woodland” was considered as one total while this category was divided into “woodland pastured” and “woodland not pastured” in the previous and later censuses.

The data organization of the 1930s is relatively similar to that of the 1940s except that there were separate categories in the 1930s for “woodland pastured” and “woodland not pastured.” On the other hand, the census of the 1920s followed a completely different structure than that used in the subsequent censuses. This census consisted primarily of improved land, woodland, and unimproved land. The 1920s definitions of “improved land” and the 1978 definition of “total cropland” are similar. The differences between these two categories are minor and lay outside the purview of this study. The “woodland” category in the 1920s census is the same as the “total woodland” category used in subsequent years.

County level data for these land use activities and crop varieties were interpolated (based on the centroid of each county) over the NBW range to generate grids with 2km×2km cell size using the inverse distance weighted (IDW) interpolated method in ArcView GIS. Once these land use and land cover patterns were interpolated, the

differences between each subsequent census year were presented as a change map to illustrate how individual land use type and crop varieties had changed spatially over the NBW range between 1920 and 1997 and the impact of agricultural policies on these changes.

RESULTS

Changes in Land Use

Total cropland (including cropland harvested, cropland used only for pasture or grazing, and other cropland)

Total cropland cover decreased dramatically and continuously between 1920 and 1997 (Fig. 3.1). Between 1920 and 1930 total cropland cover increased in the northern and southern parts of Texas, western Oklahoma, Kansas, Nebraska and eastern Colorado. However, substantial decreases occurred in almost all of the states stretching from southwestern Maine along the east coast to South Carolina and westward all the way to western Iowa, Missouri and Arkansas. But, some portions remained unchanged in eastern North Carolina, southern Florida, Alabama, and throughout most of Louisiana and Wisconsin (Fig. 3.2A). In the decade between 1930 and 1940 there was a fragmented increase in total cropland cover in many states, but that was particularly seen in Tennessee, Alabama, Arkansas, Mississippi, and some parts of Wisconsin and Michigan (Fig. 3.2B).

From 1940 through 1954, sharp decreases were observed in total cropland throughout most of the states within the NBW range, except for part of the Florida peninsula and region of Arkansas and Louisiana along the Mississippi River. Losses of total cropland were especially high in northeastern Texas, southern Oklahoma and

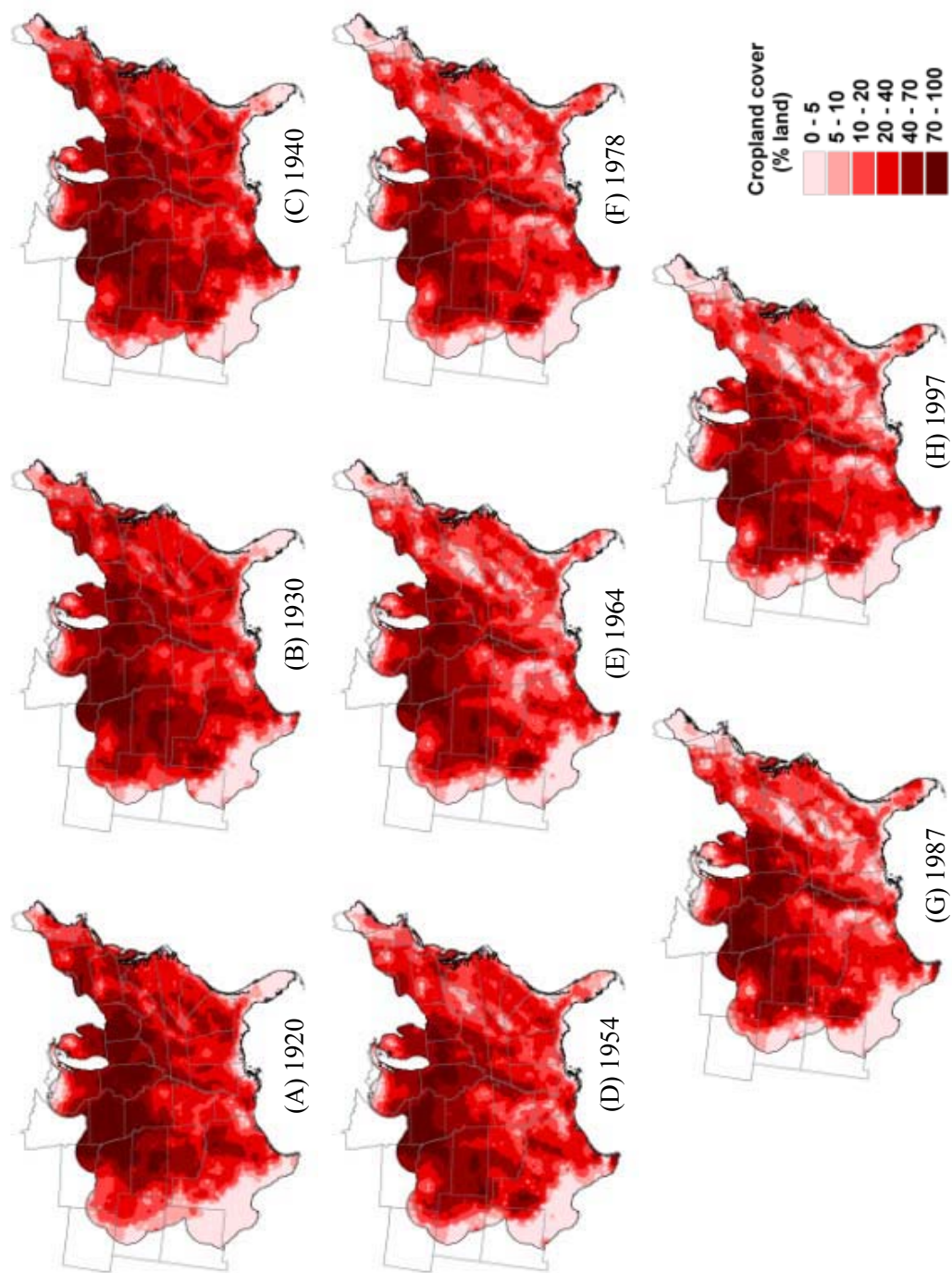


Fig. 3.1. Total cropland in the northern bobwhite range, 1920-1997

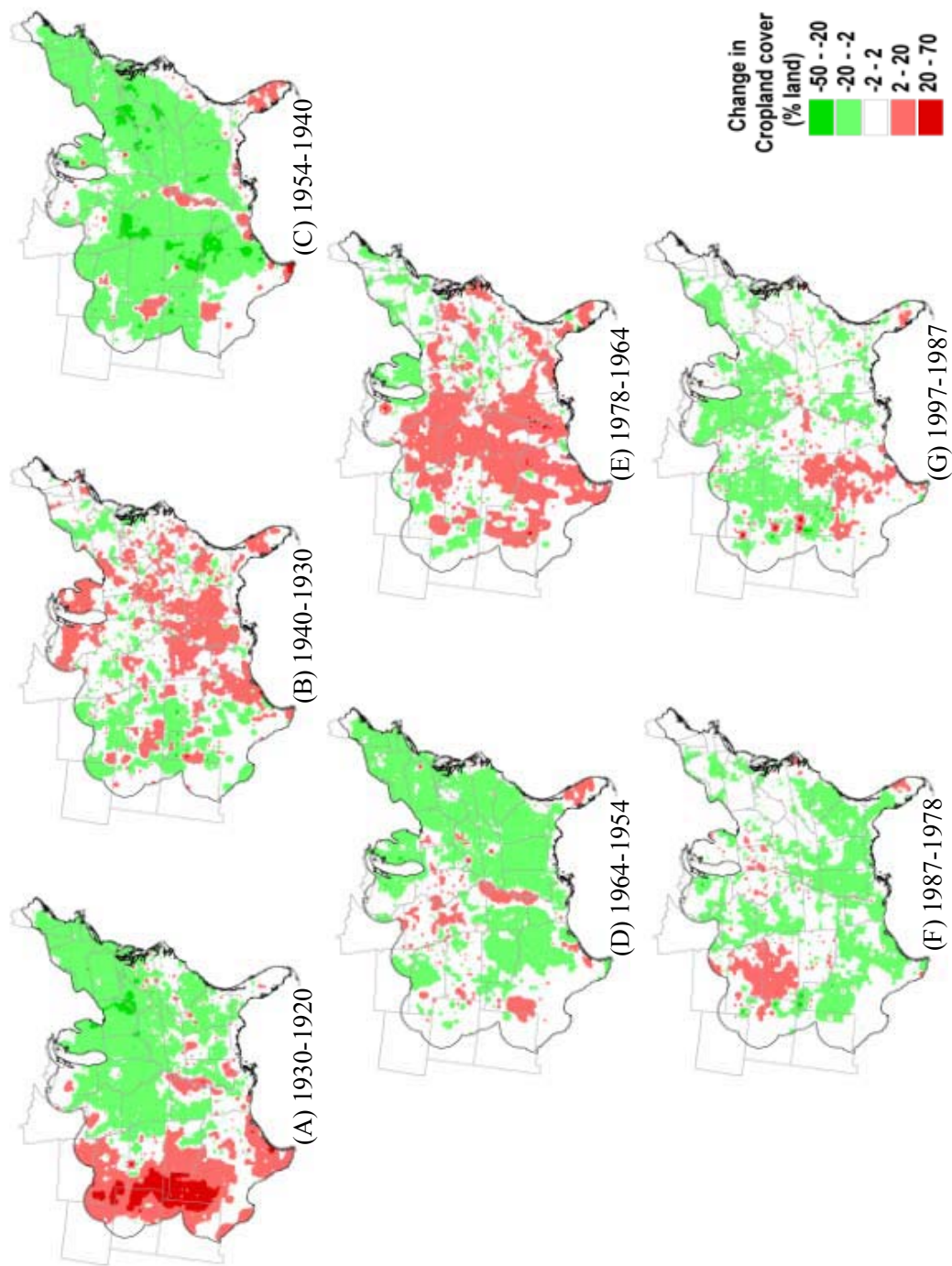


Fig. 3.2. Changes in total cropland in the northern bobwhite range, 1920-1997

Missouri during that period. However, there was a small amount of cropland gain in the southern and northwestern portions of Texas along the Mississippi River and Florida (Fig. 3.2C). From 1954 to 1964, the acreage of total cropland declined in the eastern, southeastern and southern parts of the NBW range except for a few portions in Florida and on the Arkansas-Mississippi border where the Mississippi River runs (Fig. 3.2D).

The cropland increase in central Florida continued into 1964 and through 1978. This same time period had seen extensive growth in total cropland cover in eastern and southeastern Texas, throughout most of Mississippi, Louisiana, Arkansas, Oklahoma, Missouri, Illinois, Iowa and eastern Nebraska (Fig. 3.2E). However, in the following decade between 1978 and 1987, most portions of the NBW range experienced considerable losses in total cropland. The only areas that witnessed major increases in cropland cover during the late 1970s and 1980s were eastern Kansas and Nebraska (Fig. 3.2F). In the following decade there was a reversal of this trend as cropland cover was lost in the northern and southeastern NBW range. The major gain in cropland cover during this period took place in portions of Texas and Oklahoma (Fig. 3.2G).

Cropland cover (except cropland used only for pasture or grazing)

Significant declines were noted in cropland cover from 1920 to 1997, particularly in the southern and eastern states, except some places along the Mississippi River (Fig. 3.3). A slight increase was observed in cropland cover between 1930 and 1940 in the northwestern parts of Texas along the border of New Mexico and further north towards Kansas. However, most of the states within the NBW range were experienced losses during this period, especially in areas extending from mid-eastern Texas through

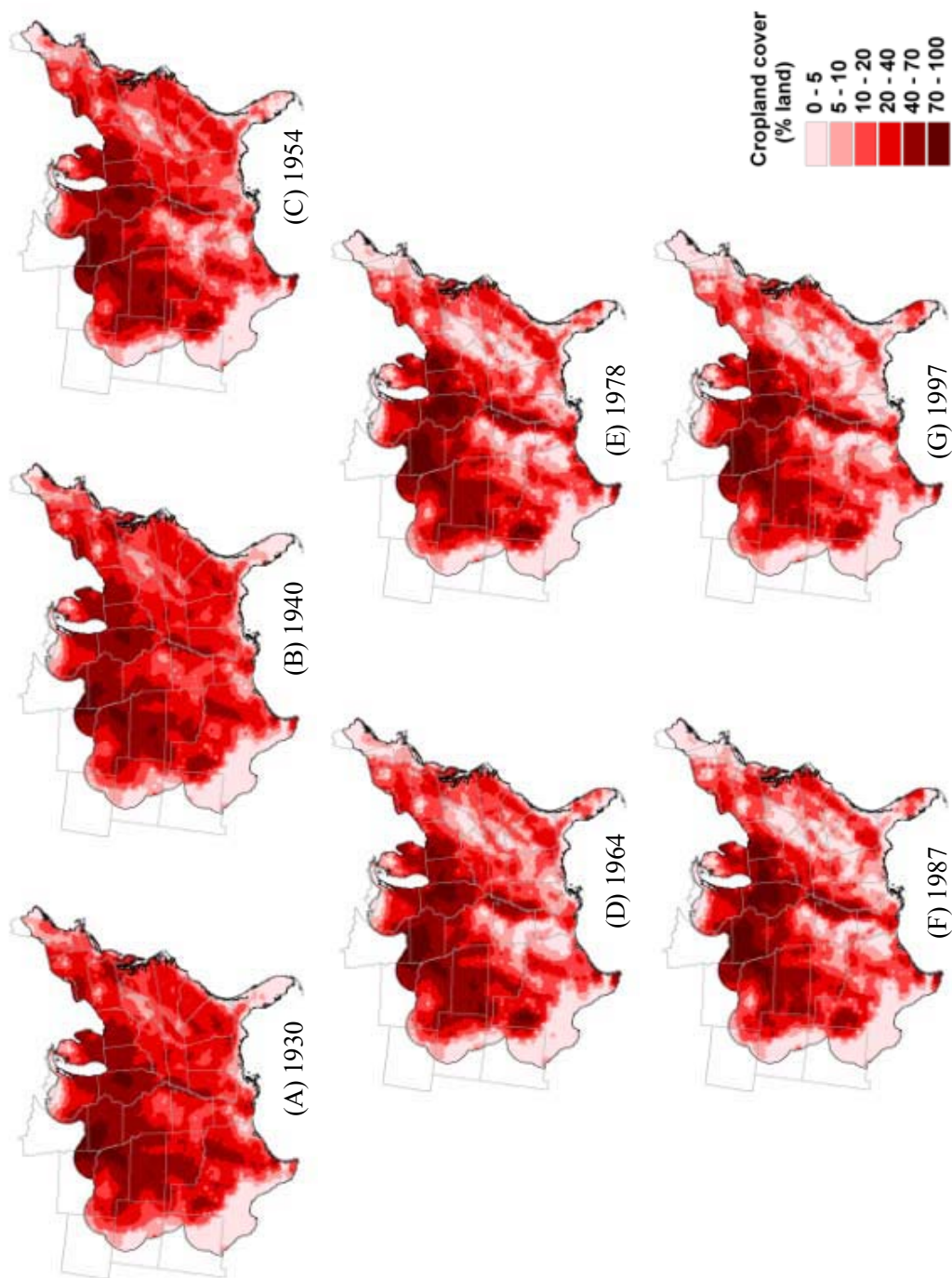


Fig. 3.3. Cropland cover (except cropland used only for pasture) in the northern bobwhite range, 1920-1997

Oklahoma, Arkansas, Missouri, Iowa, Illinois, Indiana, and Ohio. Some minor decreases were also experienced in Pennsylvania and New York during this decade (Fig. 3.4A). From 1940 through 1954, there were significant decreases in cropland cover throughout most of the eastern and central states, which contrasted with the increases in cropland cover experienced in the western and north central states (Fig. 3.4B).

Even though the pattern in cropland cover between 1954 and 1964 showed a continuation of the trend established in the previous years, some of the states in the north and northwestern part of the NBW range such as Colorado, Kansas, Missouri, and parts of Nebraska remained unchanged. Albeit there were increases in cropland cover during this period in parts of northern Iowa and Missouri stretching through Illinois, northern Indiana and Ohio. In addition, Florida and parts of Arkansas and Mississippi experienced minor cropland cover gains in this decade (Fig. 3.4C). The slight increase in cropland cover in Arkansas, Mississippi and the western Tennessee border merged with northern states and stretched down to Louisiana and coastal Texas between 1964 and 1978 (Fig. 3.4D).

From 1978 through 1987, there was little change in the amount of cropland except for some scattered areas in northern Texas through western Kansas, and some portions of the coastal states extending from Georgia through eastern Texas, which experienced substantial losses. Between 1978 and 1987 there was a small amount of cropland cover increase in the northern part of the NBW range, around the areas of Kansas, Nebraska, Missouri, Illinois, and Indiana (Fig. 3.4E). Cropland cover through the years 1987 to 1997 decreased somewhat in the south and north compared to previous decades.

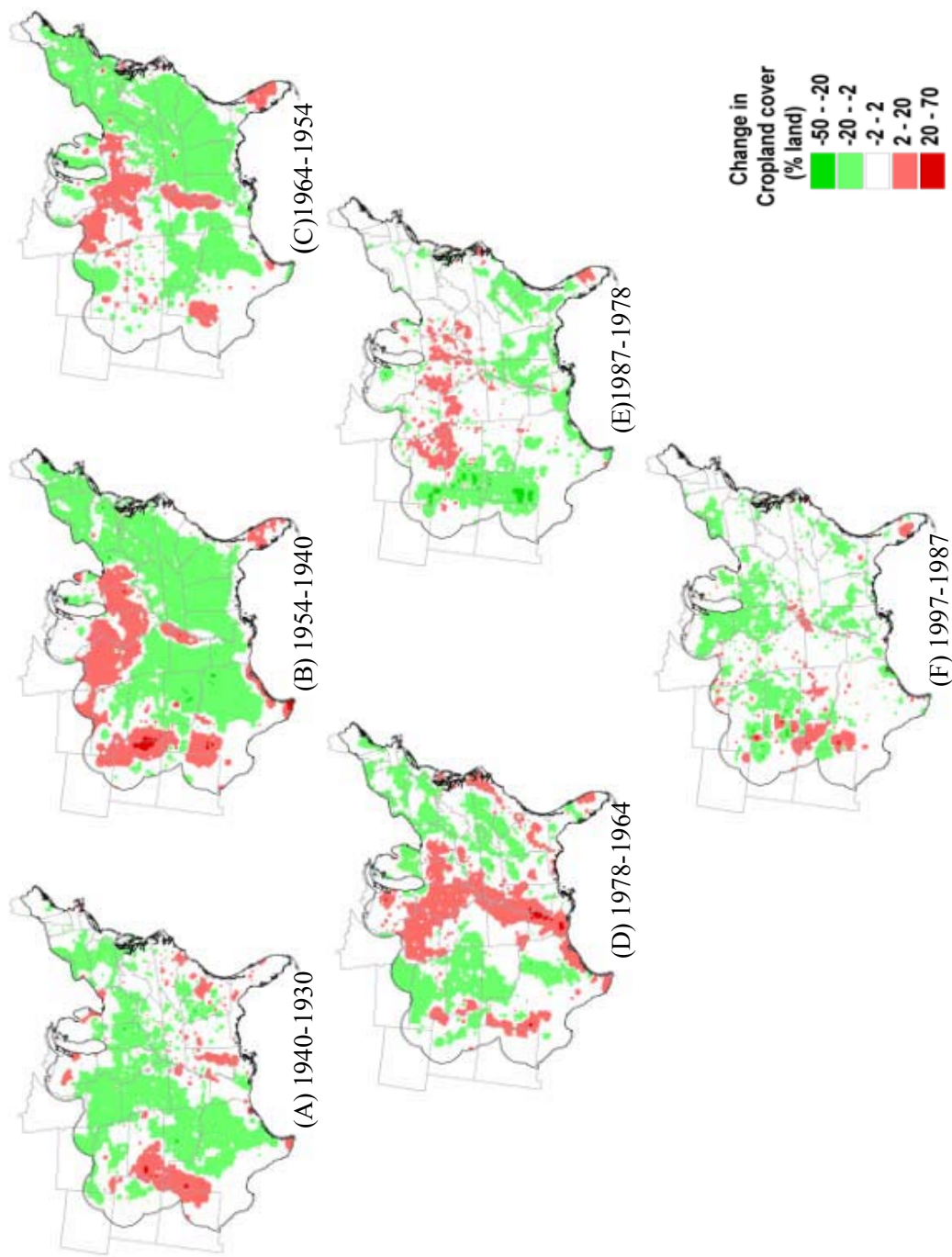


Fig. 3.4. Changes in cropland cover (except cropland used for pasture) in the northern bobwhite range, 1920-1997

However, there were slight increases in cropland cover in northern Texas, Colorado and Kansas (Fig. 3.4F).

Cropland harvested

Significant fluctuations were noted in cropland harvested between 1920 and 1997 (Fig. 3.5). Considerable losses in harvested cropland occurred between 1930 and 1940 in almost all of the western and northwestern states, but most notably in Kansas. On the other hand, some minor increases in harvested cropland occurred in South Carolina, Georgia, Louisiana, and on the north Texas-New Mexico border (Fig. 3.6A).

Contrary to the decade of the 1930s, the years following 1940 through 1954 witnessed increased yields in the area of harvested cropland in northwest Texas, Colorado, Kansas, Nebraska, Iowa, Illinois, Indiana, Ohio, and along the Mississippi River. In addition, very small portions of central Florida and the Texas coastal plains observed slight gains during that period. However, the main region of NBW territory from central Texas, north to Kansas and eastward to Maine experienced sharp declines in harvested cropland except along the Atlantic Coastal Plains (Fig. 3.6B).

The only part of the states that experienced increases in cropland harvested between 1954 and 1964 were the area bordering the Mississippi River in Arkansas, Mississippi, and Tennessee. There were some additional gains in central Florida. Losses occurred throughout most of the species range during that decade (Fig. 3.6C). Between 1964 and 1978 there was an increase in the area of cropland harvested beginning with the southern coastal plains of Texas and extending north along the Mississippi-Missouri River valley to encompass large sections of the followings states: Louisiana, Arkansas,

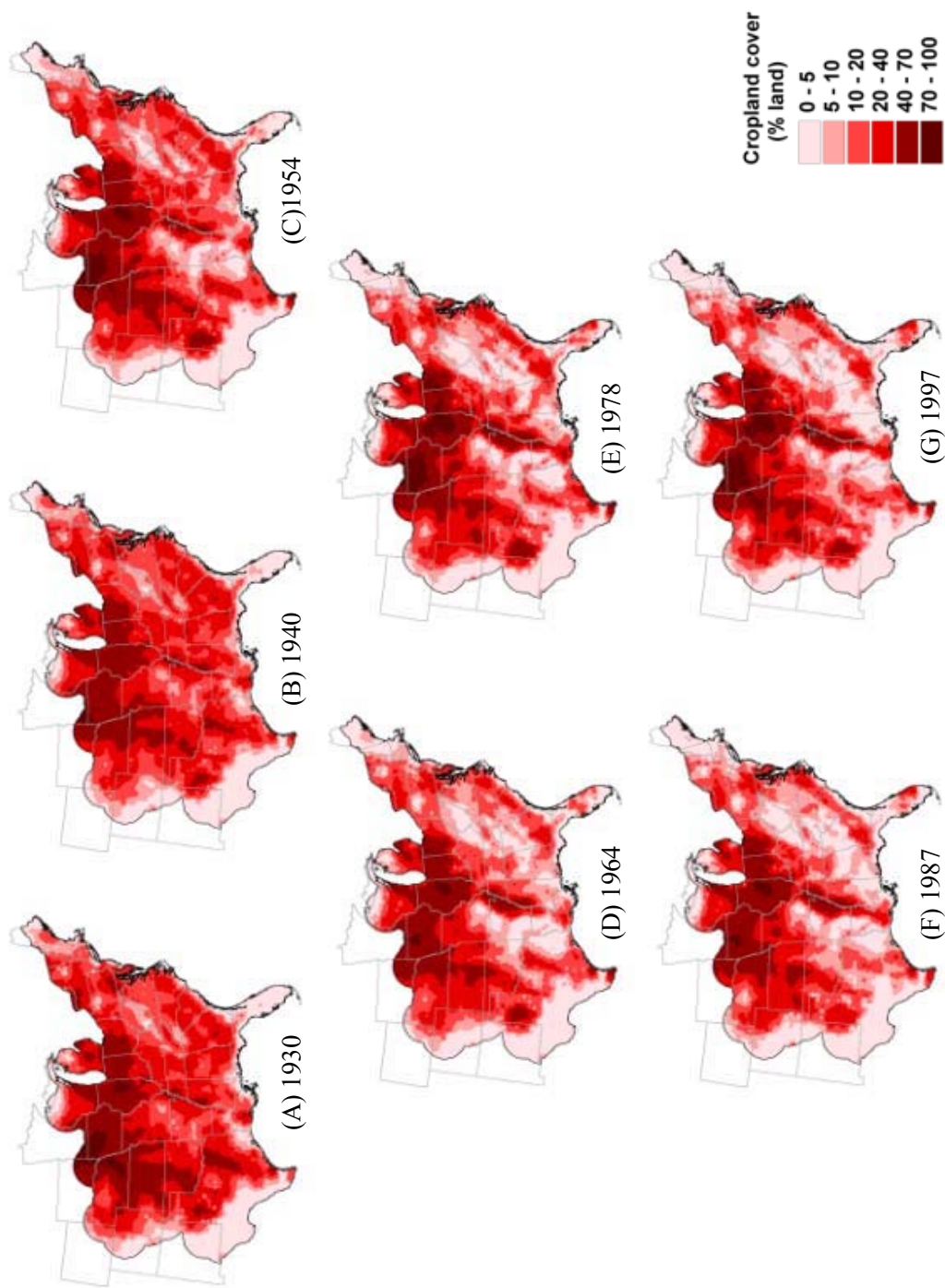


Fig. 3.5. Harvested cropland cover in the northern bobwhite range, 1920-1997

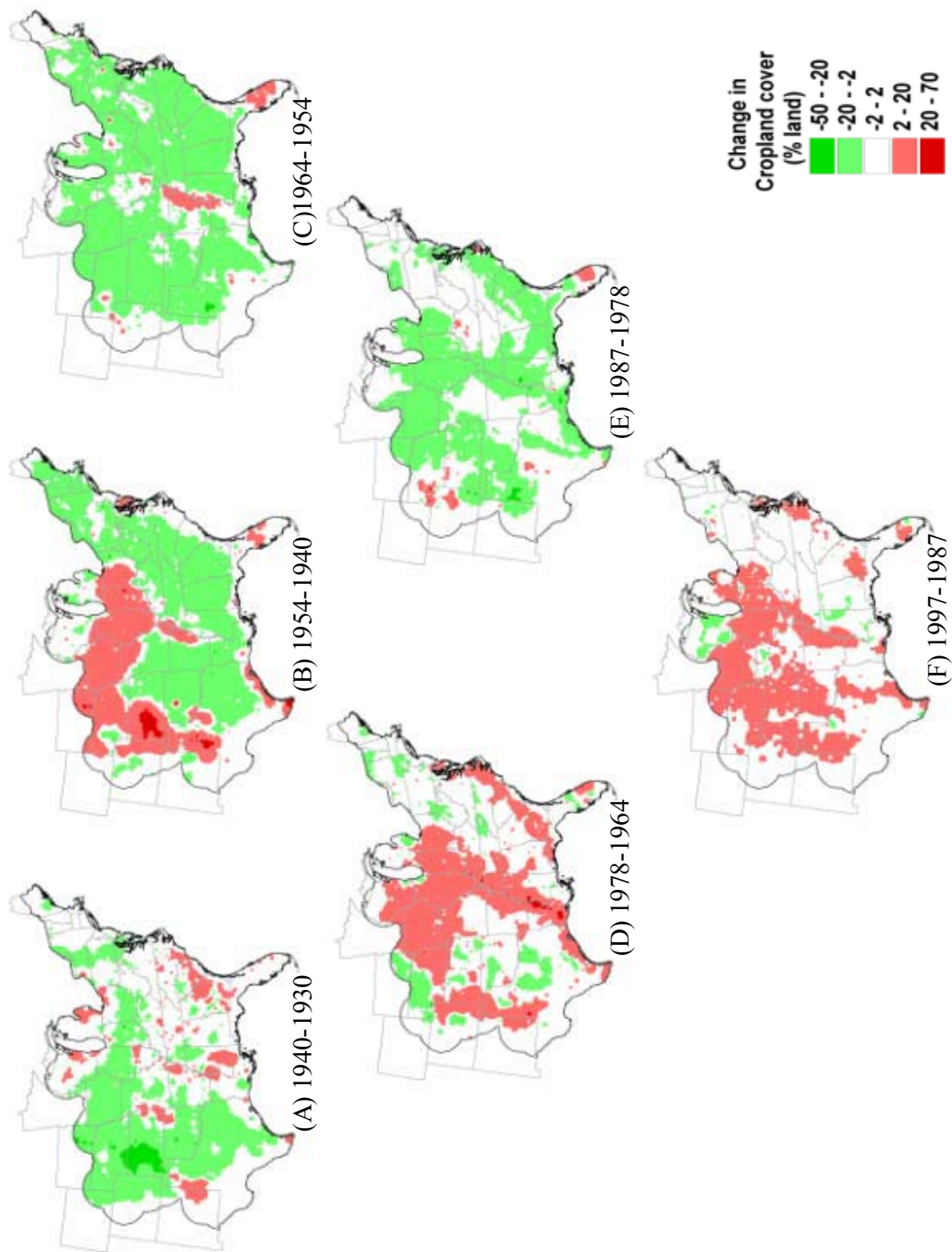


Fig. 3.6. Changes in harvested cropland cover in the northern bobwhite range, 1920-1997

Tennessee, Kentucky, Ohio, Indiana, Illinois, Wisconsin, Iowa, Missouri and Nebraska. Moreover, some increases were observed along the Atlantic coastal plains and in places stretching from the New Mexico-Texas border through that of Colorado and Kansas (Fig. 3.6D).

The places that experienced a decline in harvested cropland from 1978 to 1987 showed a similar pattern to the previous years that witnessed an increase except for eastern Kansas. During that decade, slight gains seen in eastern Colorado, western Nebraska, and central Florida (Fig. 3.6E). In the years between 1987 and 1997, Iowa, Nebraska, Illinois, Indiana and parts of Ohio, Oklahoma, Kansas, and Texas, and the Arkansas-Mississippi-Tennessee border experienced increases in harvested cropland cover while the rest of the states remained relatively stable (Fig. 3.6F).

Cropland used only for pasture or grazing

An increasing pattern in cropland used only for pasture or grazing until the 1940s was reversed, and remarkable declines were observed for the duration of the study period (Fig. 3.7). The decade of the 1930s brought losses in cover from cropland used only for pasture cover to some portions of New Mexico, the Texas panhandle, Oklahoma, Kansas, and Nebraska. The areas extending from southern Maine all the way along the coastal plains did not experience any changes in cropland used only for pasture or grazing. However, significant increases occurred in most of the remaining parts of the NBW range (Fig. 3.8A).

The years between 1940 and 1954 witnessed losses in cover from cropland pasture in almost all of the northern states and some southern ones, such as Alabama,

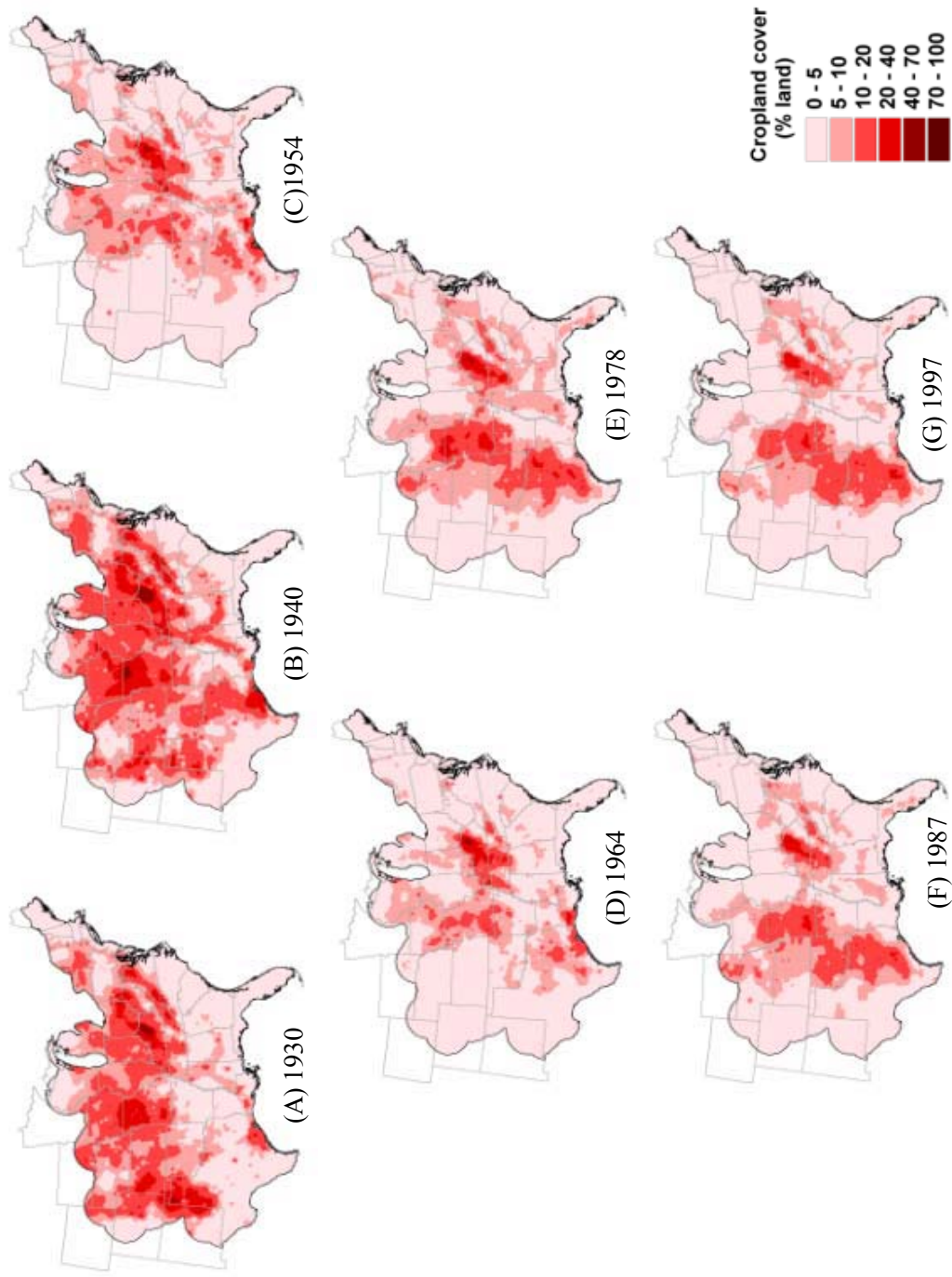


Fig. 3.7. Cropland used only for pasture cover in the northern bobwhite range, 1920-1997

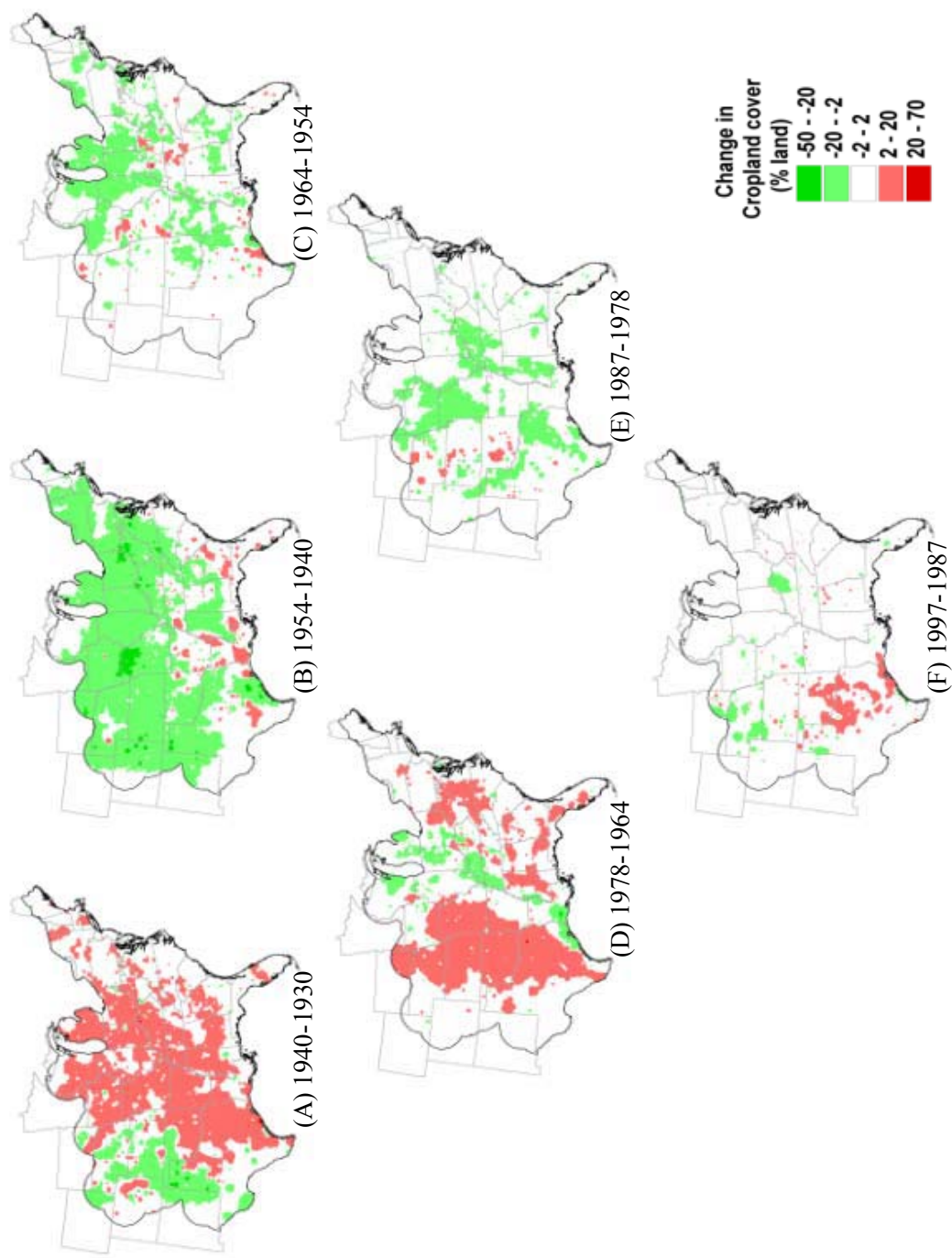


Fig. 3.8. Changes in cropland used only for pasture cover in the northern bobwhite range, 1920-1997

Mississippi and northern Texas. However, several localized and scattered increases were observed in small portions of Texas, Louisiana, Arkansas, Mississippi, Tennessee, Georgia and Florida (Fig. 3.8B). Between 1954 and 1964, the NBW range saw decreases in cover from cropland pasture throughout the northern regions of Wisconsin, Illinois, Indiana, and Ohio, while the rest of the territory showed few changes in cover from cropland pasture (Fig. 3.8C).

In the years between 1964 and 1978 there were major increases in cropland used only for pasture or grazing in many portions of Texas, Oklahoma, Kansas, Nebraska, and Missouri. Moreover, there were also minor gains in Virginia, West Virginia, North Carolina and eastern Florida all the way through eastern Mississippi. Some losses also took place along the Mississippi River in the states of Louisiana, Tennessee, Mississippi, Illinois, Ohio and Michigan with concomitant losses along the Gulf Coast Region of western Louisiana and Texas (Fig. 3.8D).

Between 1978 and 1987 considerable scattered losses were observed in the NBW range. The decline in the acreage of cropland pastured occurred mostly in the Texas panhandle and eastern Texas, Missouri, Iowa, Kentucky, Tennessee and Louisiana (Fig. 3.8E). Even though a very small amount of cropland pasture increased in eastern Texas and Oklahoma, no significant losses occurred from 1987 to 1997 (Fig. 3.8F).

Other cropland

Although other cropland showed relatively increasing trends until 1987 (Fig. 3.9A-F), significant losses were noted in the following decade (Fig. 3.9G). The availability of cover from other cropland increased considerably in western Kansas and

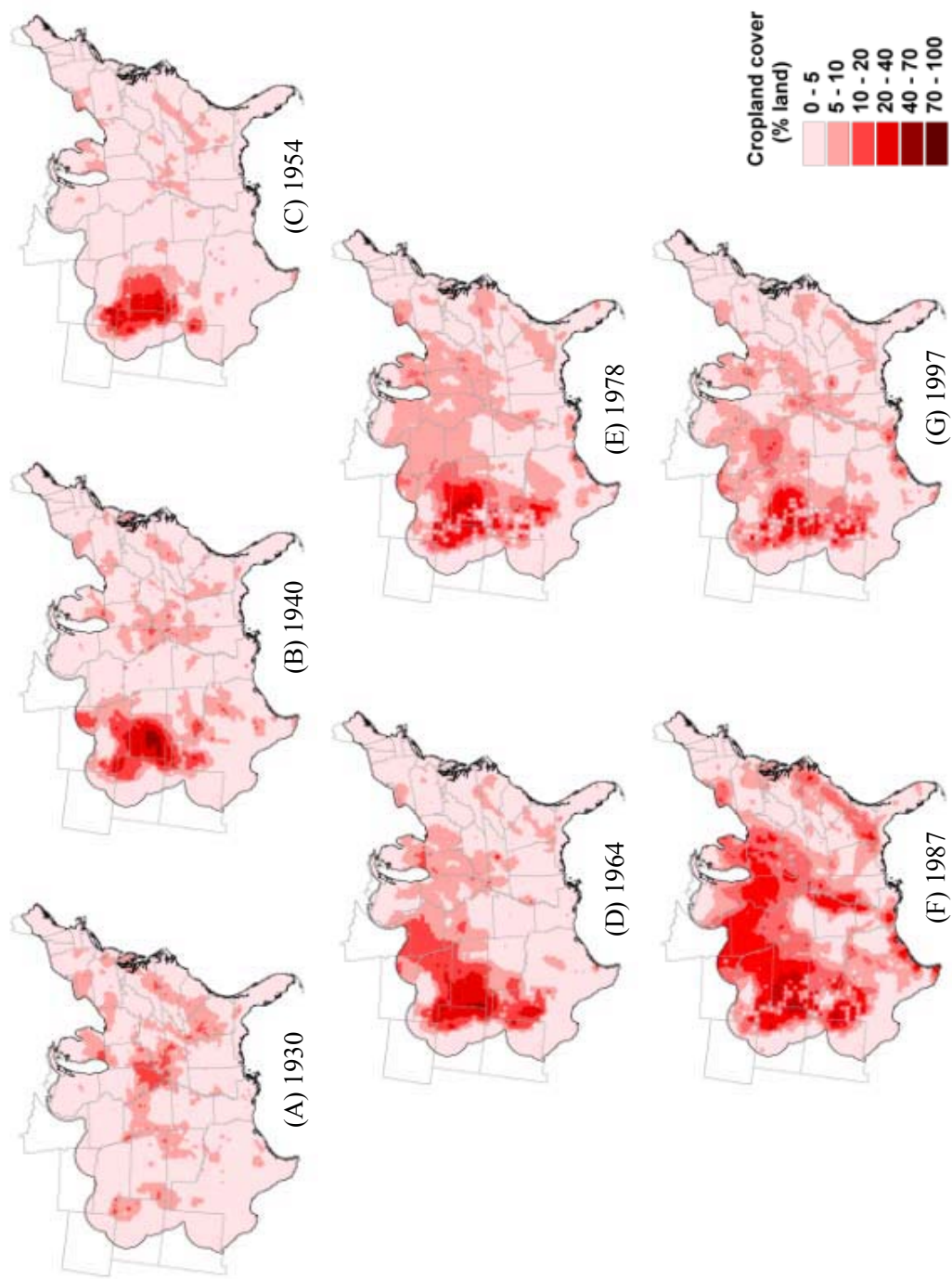


Fig. 3.9. Other cropland in the northern bobwhite range, 1920-1997

parts of Nebraska in the decade of the 1930s. However, the remaining states in the range observed either no or insignificant amounts of increases or losses in other cropland cover (Fig. 3.10A). This situation did not change between 1940 and 1954 where most of the states saw no change except for parts of Nebraska and western Kansas where considerable losses occurred (Fig. 3.10B).

Between 1954 and 1964, northern Texas, western parts of Kansas, and eastern parts of Nebraska experienced increases (Fig. 3.10C), whereas the same area underwent significant losses in other cropland cover between 1964 and 1978 (Fig. 3.10D). Significant increases were observed from 1978 to 1987 in the states stretching from northern Texas and Kansas through Nebraska, Iowa, Illinois, Ohio, and along the Mississippi River (Fig. 3.10E). The same states experienced increases in the previous decade and witnessed losses in the decade of 1987 and 1997 (Fig. 3.10F).

Cropland failed

The most severe failure in cropland cover over the 70-year period was experienced in the 1940s (Fig. 3.11). Between 1930 and 1940, cropland failure was observed in northern Texas and New Mexico, western Kansas, and northern Nebraska (Fig. 3.12A). However, the situation reversed in the years between 1940 and 1964, and losses of cover occurred due to cropland failure in the same area (Fig. 3.12B). No considerable changes occurred between 1964 and 1997. Slight losses and gains were observed in northern Texas between 1964 and 1978 (Fig. 3.12C), while only decreases were observed in the Texas Panhandle between 1978 and 1987 (Fig. 3.12D).

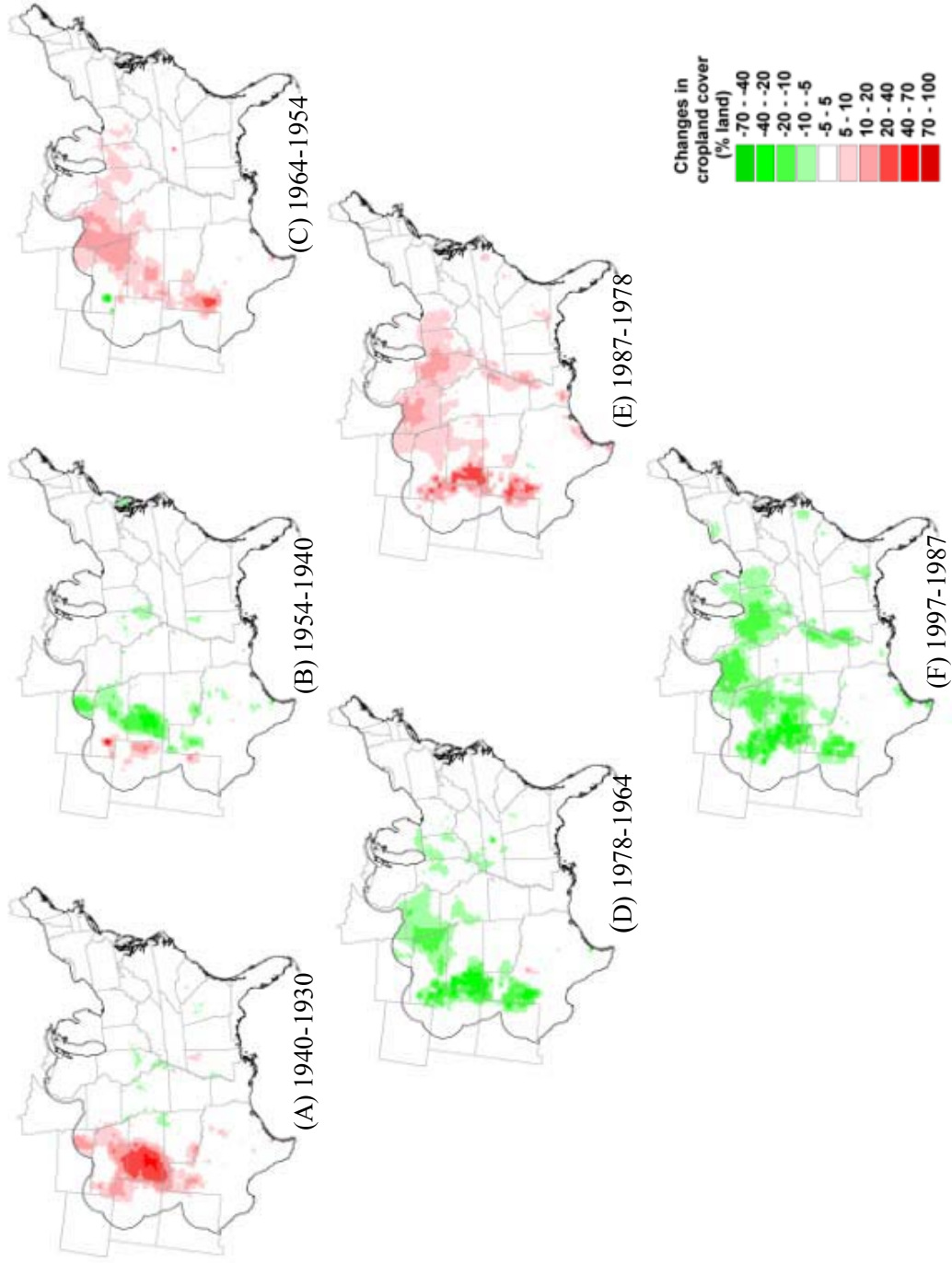


Fig. 3.10. Changes in other cropland in the northern bobwhite range, 1920-1997

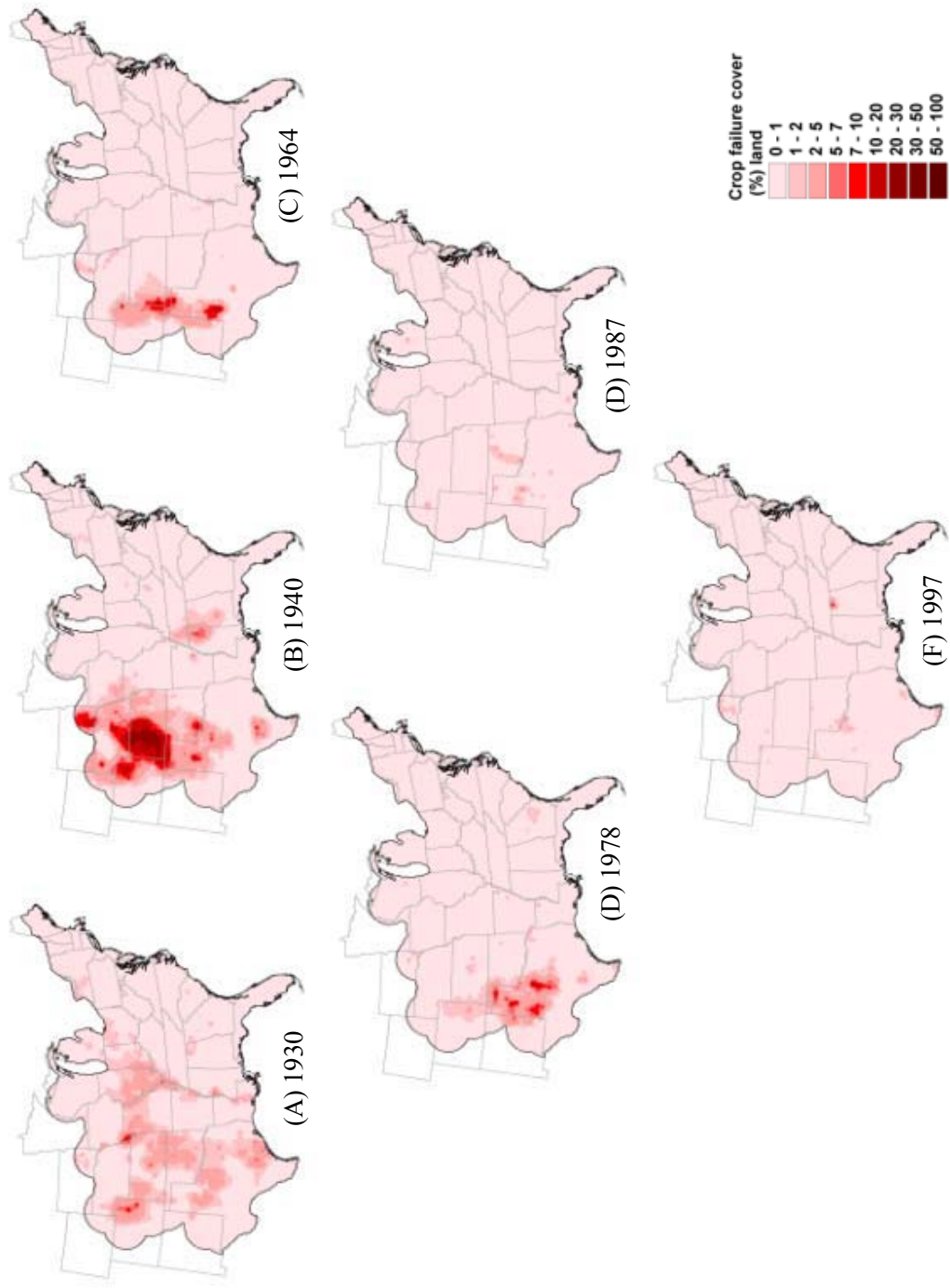


Fig. 3.11. Cropland failure in the northern bobwhite range, 1920-1997

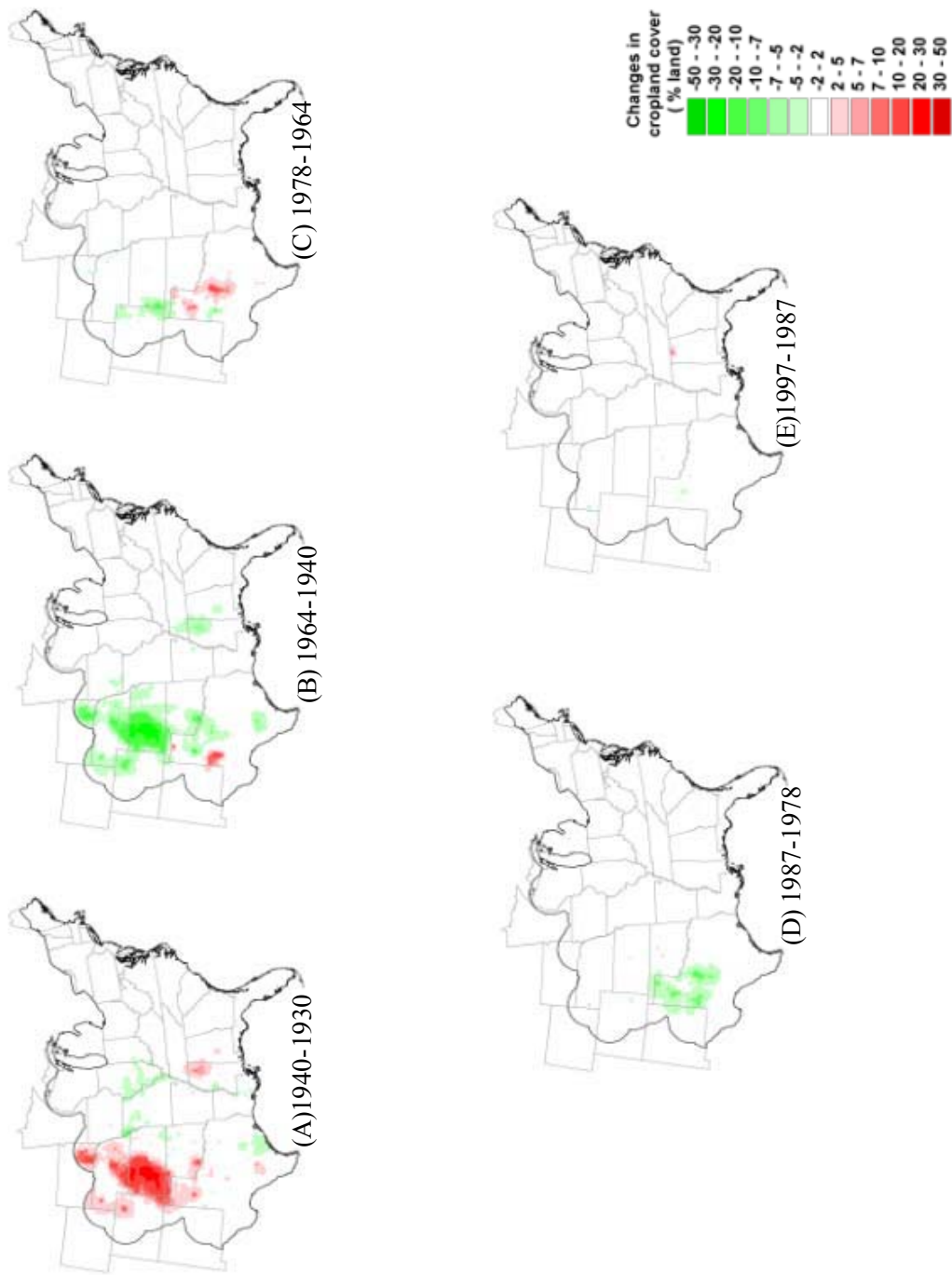


Fig. 3.12. Changes in cropland failure in the northern bobwhite range, 1920-1997

Cropland idle

Significant fluctuations were observed in cropland idle between 1920 and 1997 (Fig. 3.13). Idle cropland area increased during the decade of 1930 and 1940 extending from northern and eastern Texas through most parts of Kansas and Nebraska. The rest of the range experienced uneven and partial losses especially in Georgia and South Carolina (Fig. 3.14A). Between 1940 and 1954 large losses were mostly concentrated in eastern and northern Texas, in western Kansas, and in most parts of Oklahoma, Iowa, Indiana, Illinois and Tennessee (Fig. 3.14B).

From 1954 to 1964 losses in idle cropland continued intensively in eastern Colorado and most parts of Kansas. Some losses were seen in much of Arkansas, Tennessee, and Alabama (Fig. 3.14C). In the years between 1964 and 1978, idle cropland decreased in northern Mississippi, Alabama, Georgia, and South Carolina. In addition, some losses occurred in some portions of Tennessee, Wisconsin, New York, and Pennsylvania (Fig. 3.14D).

From 1978 through 1987, however, there had been considerable increases in Iowa, Illinois, Indiana, Ohio, Kansas, parts of Nebraska and northern Texas, and on the border of Arkansas, Tennessee, Mississippi, the south eastern coastal area of Texas and through a line starting from southern Alabama to Georgia, South Carolina, and eastern North Carolina (Fig. 3.14E). The situation reversed dramatically between 1987 and 1997, and the same areas, which experienced gains in the previous decade, witnessed losses during that decade (Fig. 3.14F).

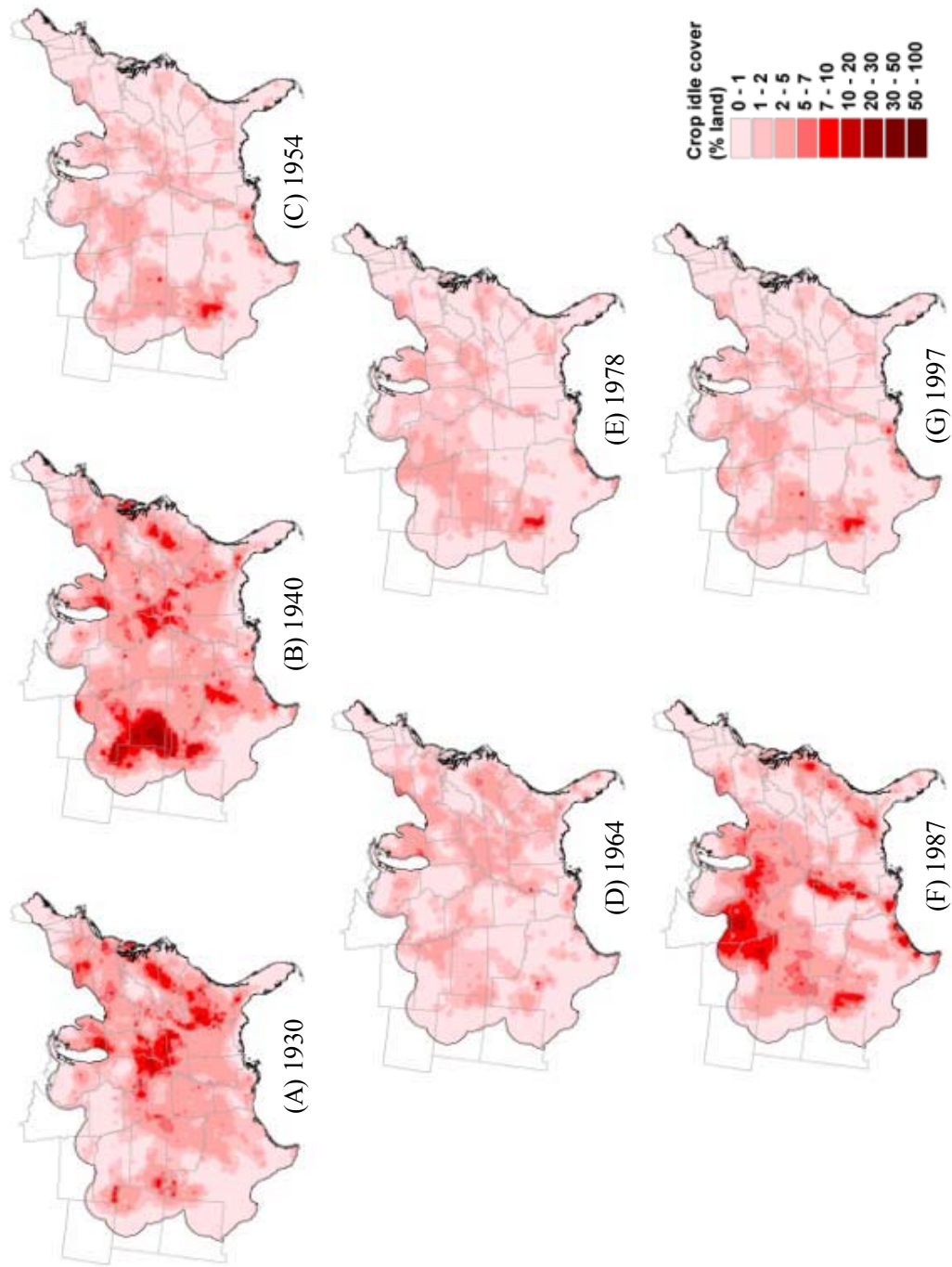


Fig. 3.13. Cropland idle cover in the northern bobwhite range, 1920-1997

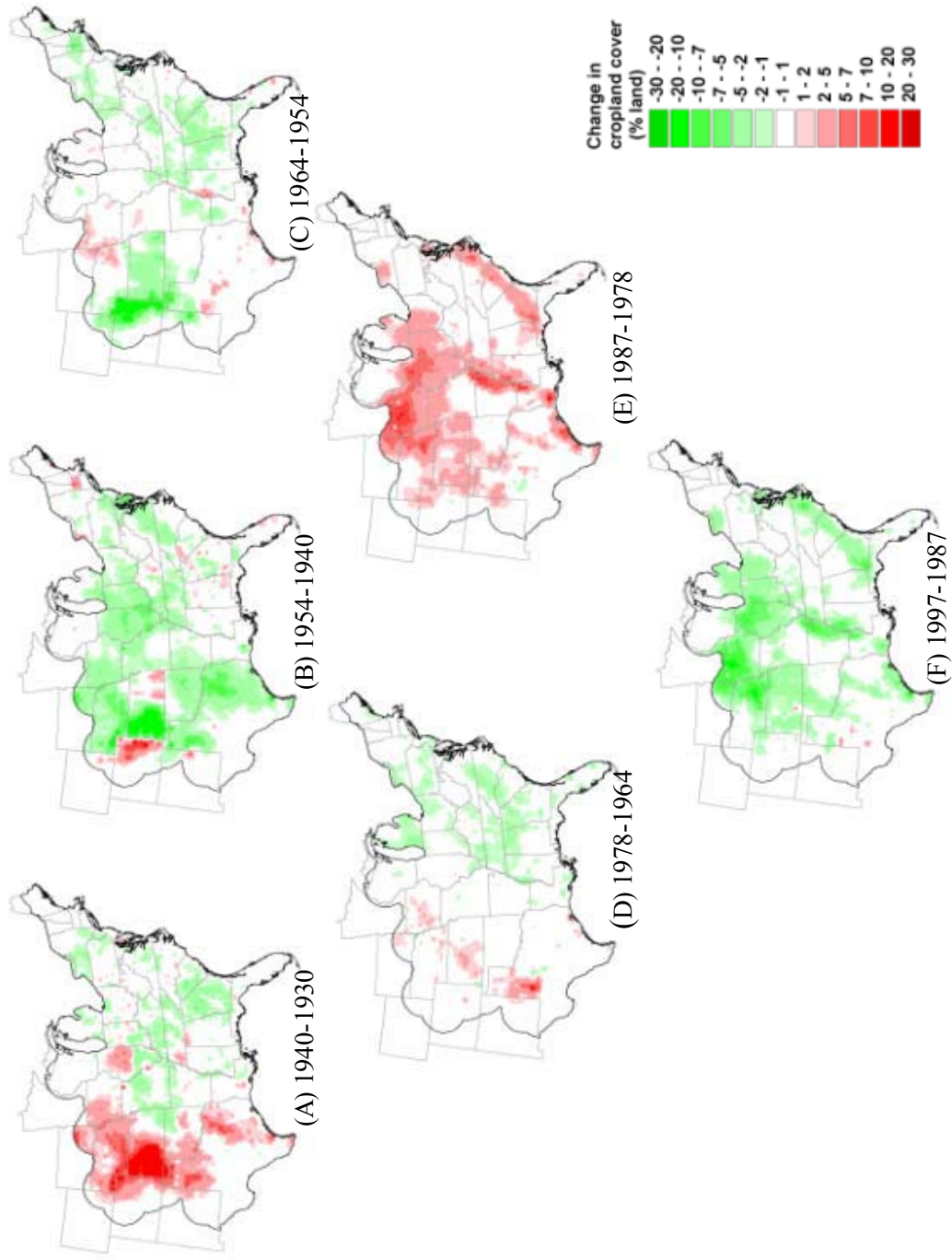


Fig. 3.14. Changes in cropland idle cover in the northern bobwhite range, 1920-1997

Total woodland

During the last 70 years, significant changes were seen in total woodland cover particularly in southern and southeastern states, while the remaining western and northern states experienced slight changes (Fig. 3.15). Between 1920 and 1930 only middle portions of Texas had a considerable increase in total woodland cover throughout the NBW range. Large losses occurred in south and southeastern states including some parts of Missouri and Kentucky. In addition, total woodland decreased in much of Illinois, Delaware, Maryland, New Jersey, Pennsylvania, Connecticut, Massachusetts and New Hampshire during that decade (Fig. 3.16A).

In the decade of 1930 and 1940, there had been losses in mid Texas and Oklahoma and some parts of Missouri, Iowa, Illinois, Wisconsin, Vermont, New Hampshire, and Massachusetts. However, significant gains were observed in southern Texas, the Mississippi River and almost all southeastern states (Fig. 3.16B). The years between 1940 and 1954 witnessed boosts in total woodland cover in most of the states excluding western states where almost no change was experienced. The increases in those years were intense along the southern coastal areas and in Oklahoma, Missouri and Wisconsin (Fig. 3.16C).

Those trends in the previous decade were reversed in the decade between 1954 and 1964, when most of the southern and eastern states experienced major losses in total woodland. The losses in that decade were concentrated mostly in the states of Mississippi, Alabama, Georgia, South Carolina, North Carolina, Tennessee, and Virginia. Only a slight increase was observed in southeastern Texas at that time (Fig. 3.16D). The losses continued intensively in the same area between 1964 and 1978 (Fig. 3.16E).

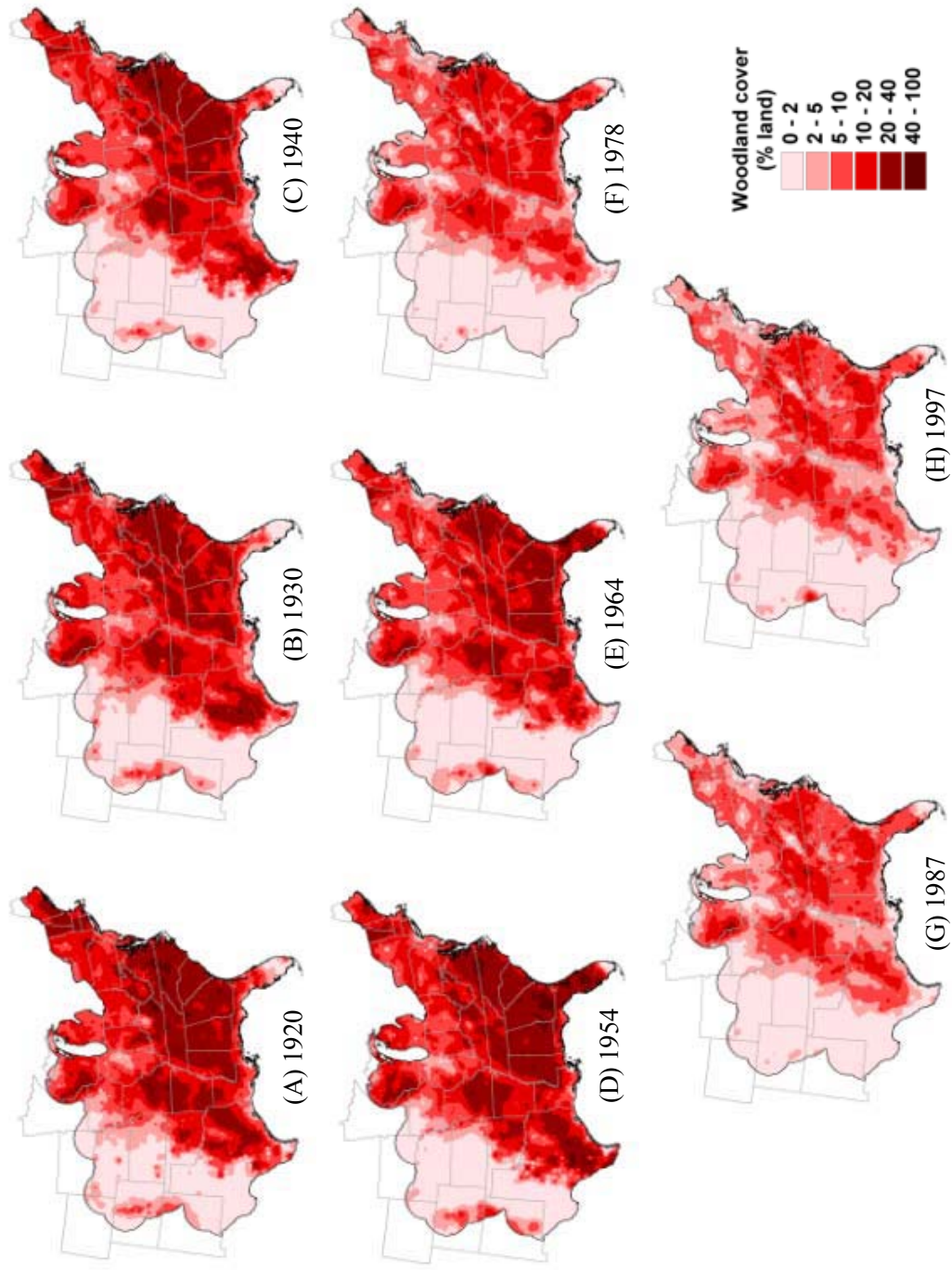


Fig. 3.15. Total woodland in the northern bobwhite range, 1920-1997

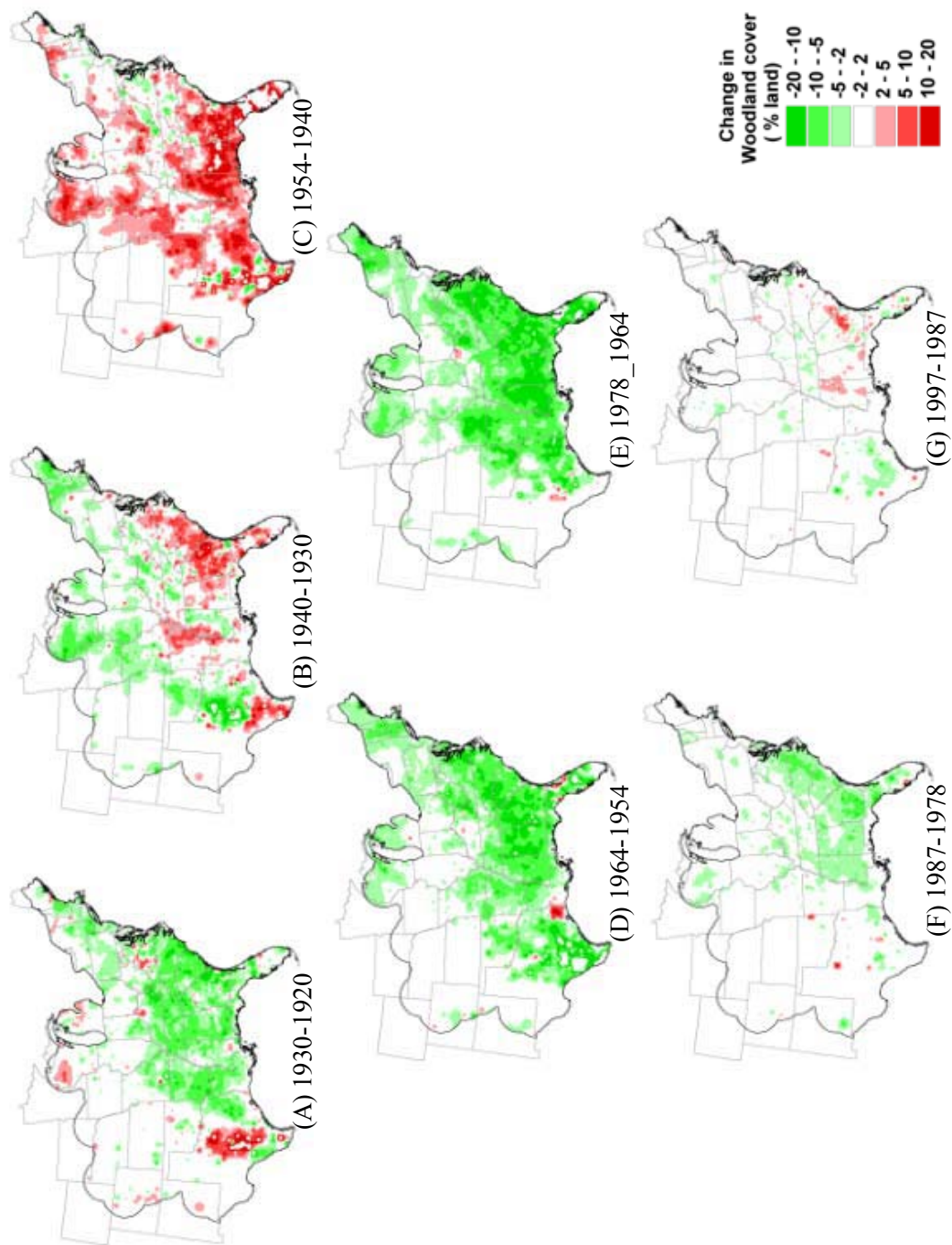


Fig. 3.16. Changes in total woodland in the northern bobwhite range, 1920-1997

By 1987 the intensity of the losses had diminished. The only states experiencing decline in total woodland were Mississippi, Alabama, Florida, Georgia, South Carolina, North Carolina and Virginia (Fig. 3.16F). No significant changes in woodland cover took place from 1987 through 1997 except for negligibly small and uneven changes (Fig. 3.16G).

Woodland pastured

Although cover of woodland pastured increased significantly until the 1940s, notable declines were observed in the following decades (Fig. 3.17). In the decade from 1930 to 1940 woodland pastured cover declined mostly in mid Texas and on the edge of Iowa, Illinois, and Missouri. However, significant gains occurred in almost all of the states extending from southwestern Maine along the coast almost all the way to eastern Texas, Missouri, Illinois, Indiana, Ohio, Pennsylvania and New York (Fig. 3.18A).

The increasing pattern reversed in the following decade, within the same area except from some portions of Texas, which observed decreases from 1940 to 1954. Southern and eastern Texas, Oklahoma, and several parts of Missouri, Illinois and Florida witnessed gains that decade (Fig. 3.18B). Between 1954 and 1964, cover from woodland pastured diminished substantially in almost all of the south and southeast states, and in the northern states including Wisconsin, Michigan, Indiana, West Virginia, and Missouri (Fig. 3.18C).

The decline in this cover type continued at the same places from 1964 through 1978 (Fig. 3.18D). The situation in woodland pastured did not significantly change in the years between 1978 and 1987 throughout the states except for slight decreases in Texas,

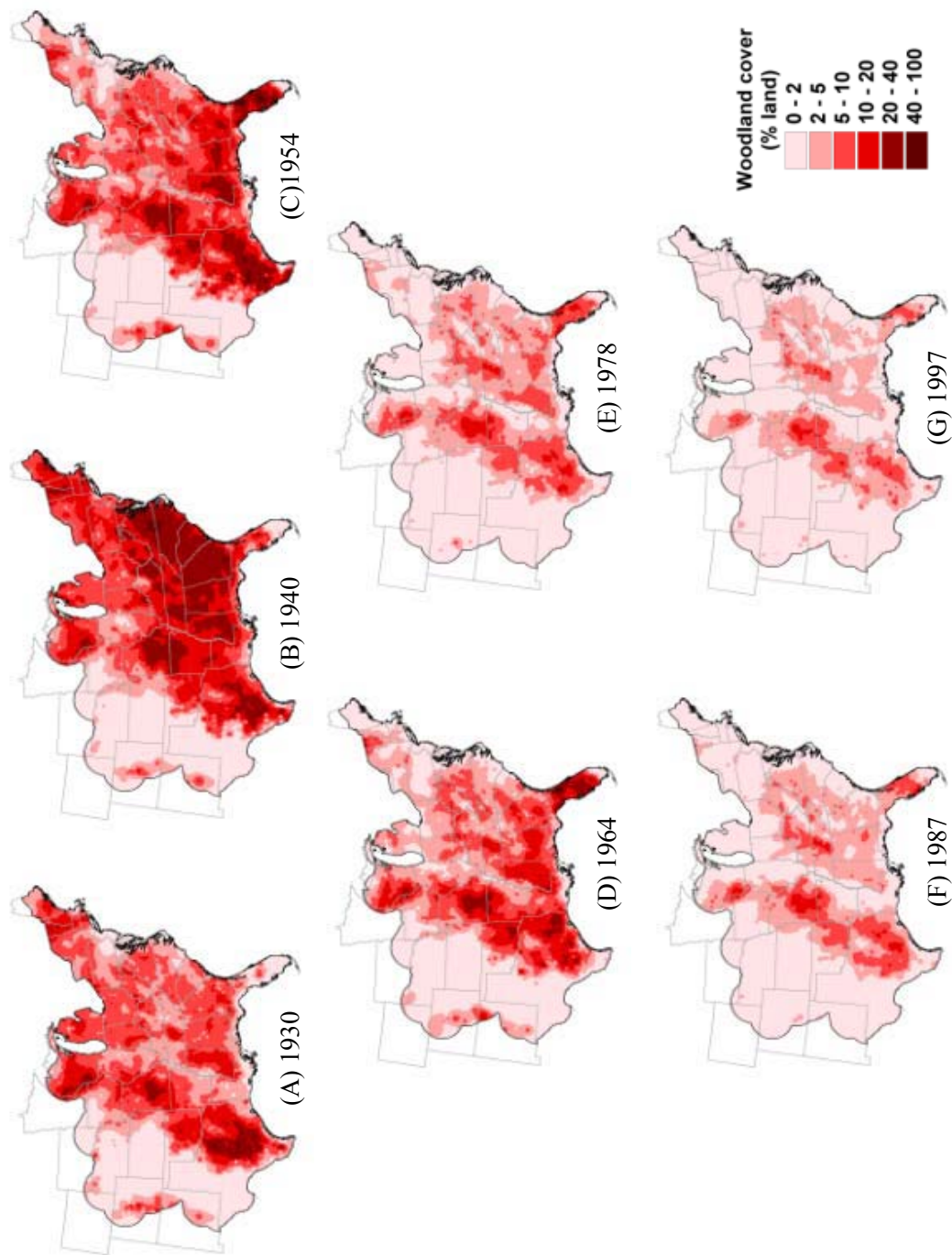


Fig. 3.17. Woodland pastured in the northern bobwhite range, 1920-1997

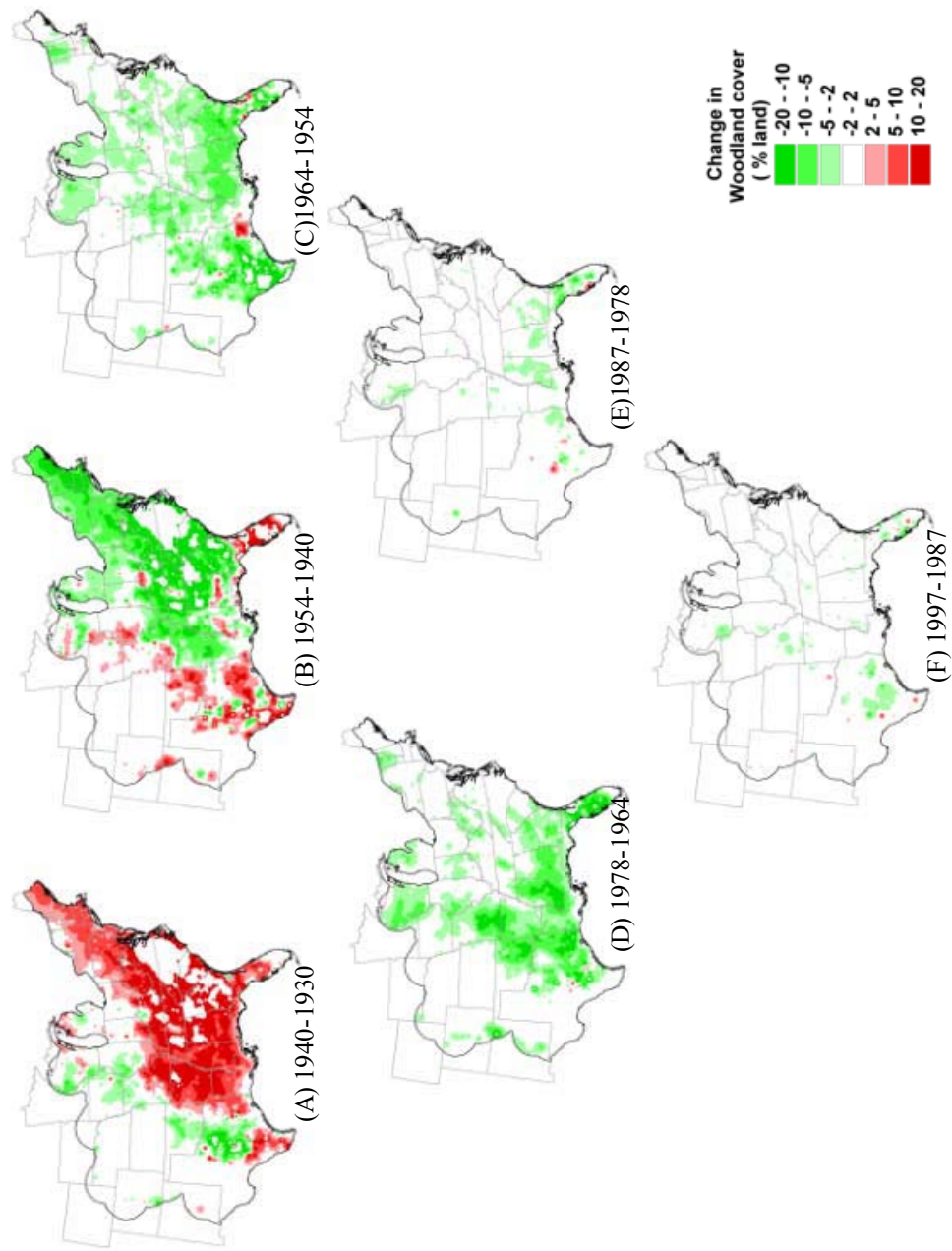


Fig. 3.18. Changes in woodland pastured in the northern bobwhite range, 1920-1997

Louisiana, Mississippi, Alabama, Florida, and Wisconsin (Fig. 3.18E). There were very minor declines observed in southern Texas, Missouri, and Wisconsin between 1987 and 1997 (Fig. 3.18F).

Woodland not pastured

The cover of woodland not pastured, like woodland pastured, showed an increasing trend until the 1940s. However, this trend was reversed and considerable decreases were noted in later decades (Fig. 3.19). In the years between 1930 and 1954 very intensive boosts were seen in woodland not pastured especially in the coastal plains, piedmont and delta regions. In addition, some gains were observed in much of Maine, Vermont, Ohio, Michigan, and Wisconsin in that period. The decline was noticed at the same time in Louisiana, Oklahoma, Tennessee, Kentucky, and Virginia (Fig. 3.20A).

The decreases in woodland cover were observed in almost all the states along the coast and the states including the piedmont and uplands region from 1954 through 1964 (Fig. 3.20B). The following decade showed very similar patterns to the previous decade (Fig. 3.20C). Most decreases were experienced in the southeastern states, particularly in Georgia, South Carolina and North Carolina between 1978 and 1987 (Fig. 3.20D). In following decade, Mississippi, Alabama, Georgia, and Florida were witnessed very minor gains (Fig. 3.20E).

Total pastureland

Total pastureland decreased considerably from 1930 through 1997 (Fig. 3.21). Between 1930 and 1954 the lower two thirds of the NBW range increased in total

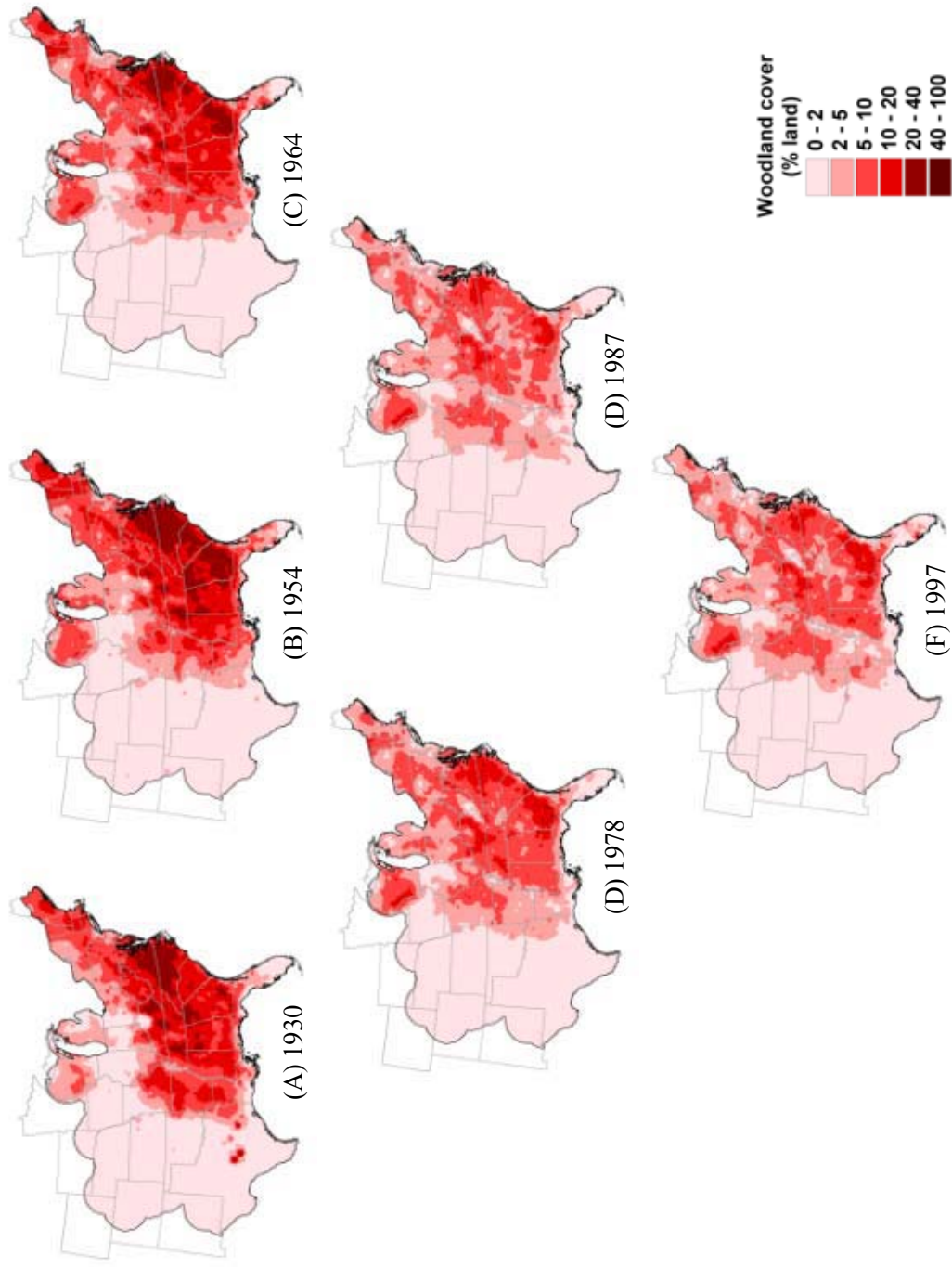


Fig. 3.19. Woodland not pastured in the northern bobwhite range, 1920-1997

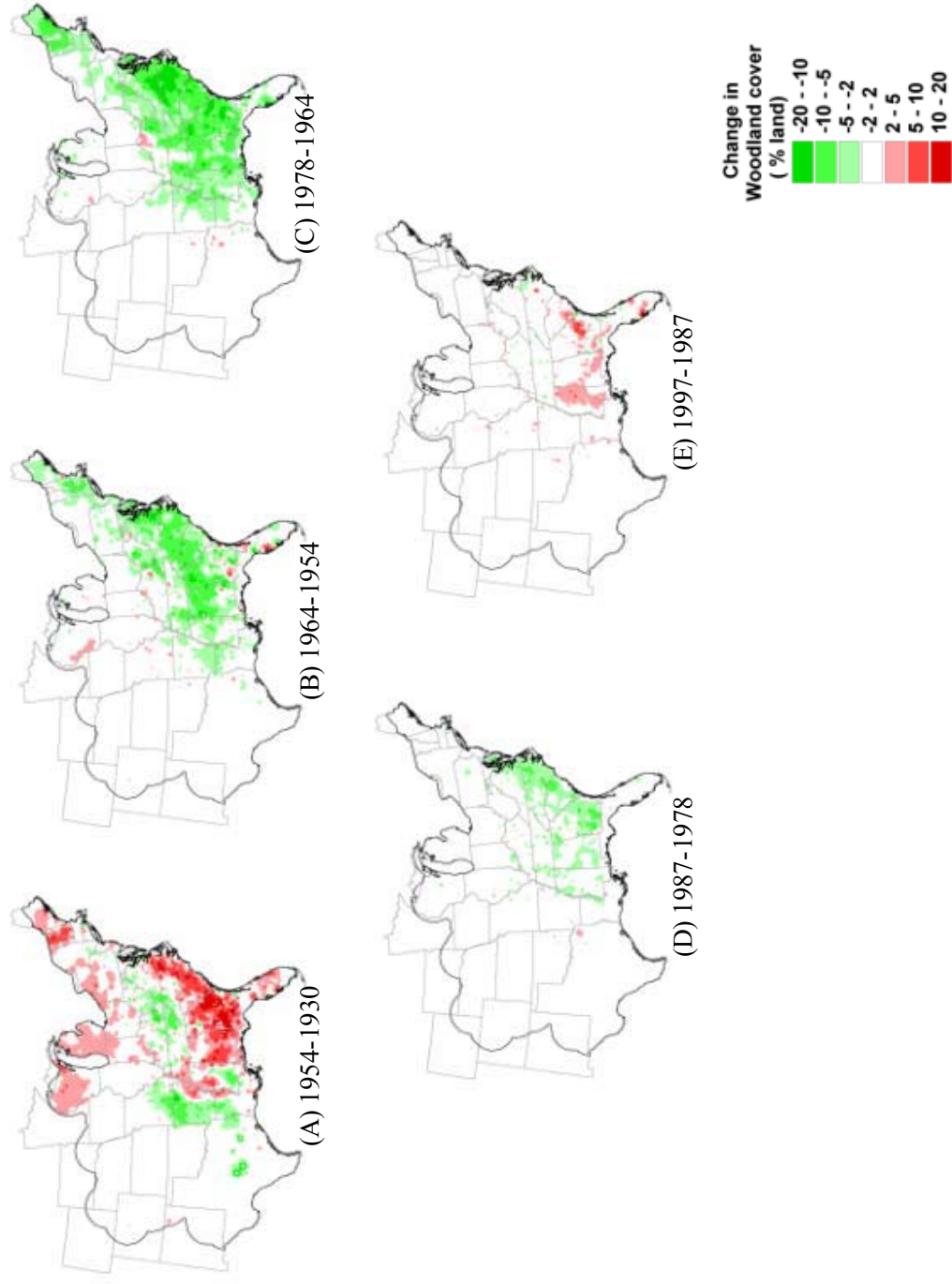


Fig. 3.20. Changes in woodland not pastured in the northern bobwhite range, 1920-1997

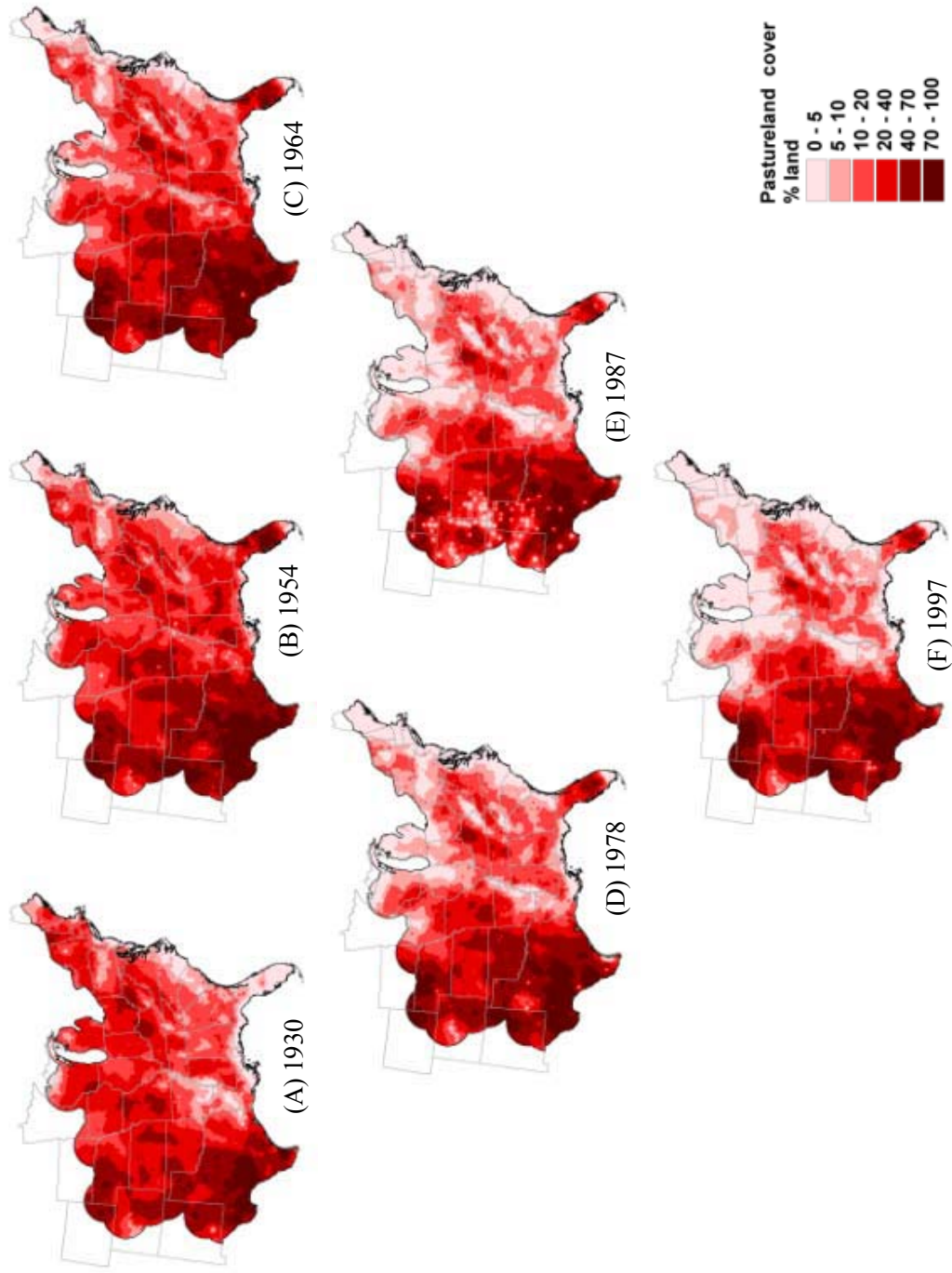


Fig. 3.21. Total pastureland in the northern bobwhite range, 1920-1997

pastureland a few decreasing spots in the Texas panhandle and in Kansas. Total acreage of pastureland dropped in the upper parts of the range in the same period (Fig. 3.22A). In the decade between 1954 and 1964 total pastureland declined almost all over the range except in the states located in the Great Plains (Fig. 3.22B).

Similar patterns were also observed in the following decades. A few increases occurred along the western edge of the range between 1964 and 1978 (Fig. 3.22C), whereas very few gains took place only in southern and western Texas in the years between 1978 and 1987 (Fig. 3.22D). The decreasing pattern in total pastureland cover continuing since 1954 was reversed and significant increases were observed in the western and southern NBW range between 1987 and 1997 (Fig. 3.22E).

Pastureland and rangeland other than cropland and woodland pastured

The increasing trend in this cover continued until 1964, and some decreases were noted in the following decades (Fig. 3.23). The acreages of pastureland and rangeland other than cropland and woodland pastured showed an escalating trend between 1930 and 1954 in almost all the states in the Great Plains and most of the southeastern parts of the NBW range except much of Georgia, South Carolina, and North Carolina. During that period, very small declines occurred in Maine, Vermont, New Hampshire, New Jersey, Massachusetts, Rhode Island, Wisconsin and Michigan (Fig. 3.24A).

The increasing tendency continued only in most portions of Texas and Oklahoma, and partly in Kansas and Nebraska in the decade between 1954 and 1964. In that period, decreases were seen mostly in Vermont, New York, Ohio, West Virginia, Missouri, New Mexico, and Florida (Fig. 3.24B). Between 1964 and 1978, almost entire NBW range

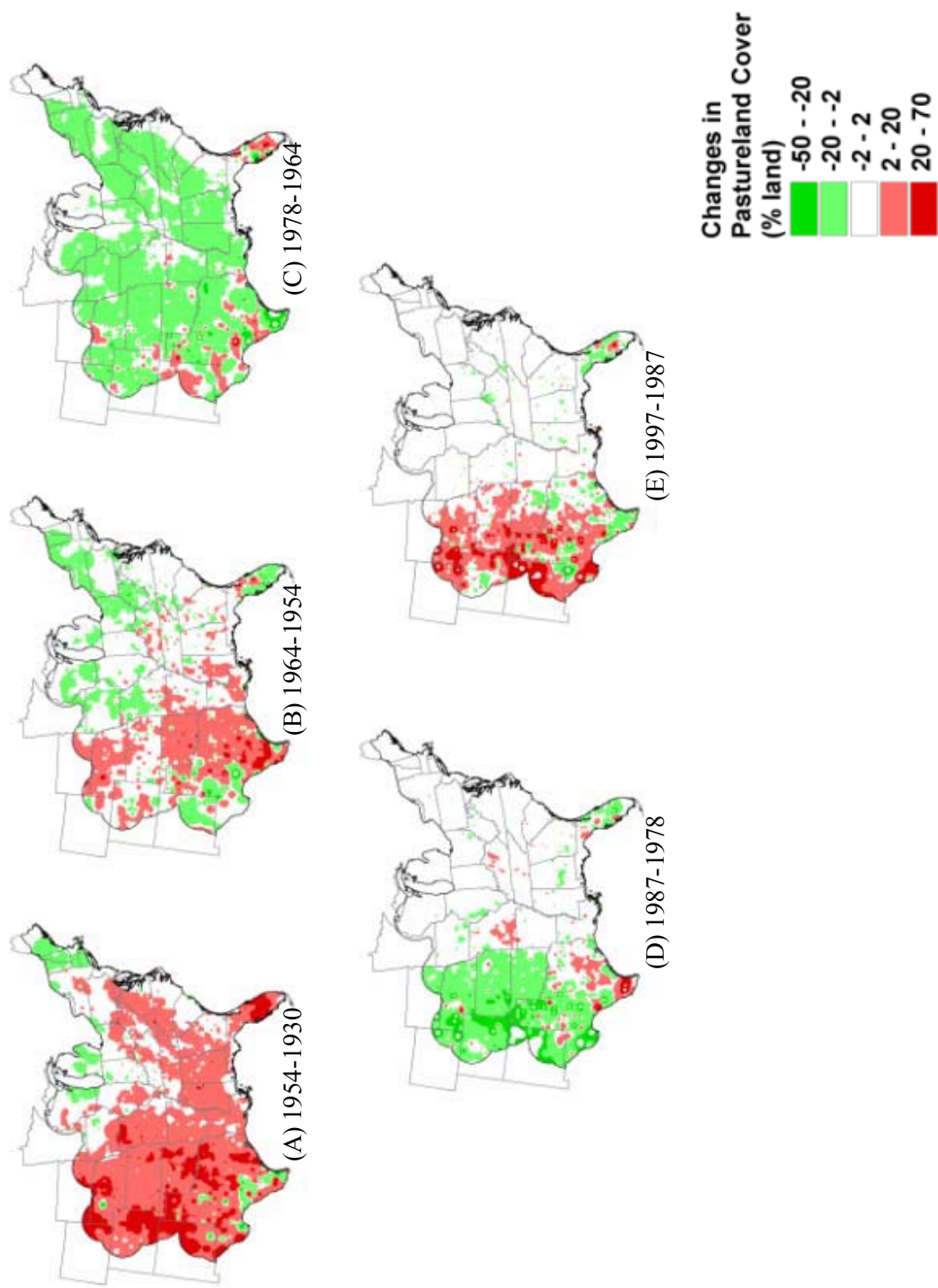


Fig. 3.22. Changes in total pastureland in the northern bobwhite range, 1920-1997

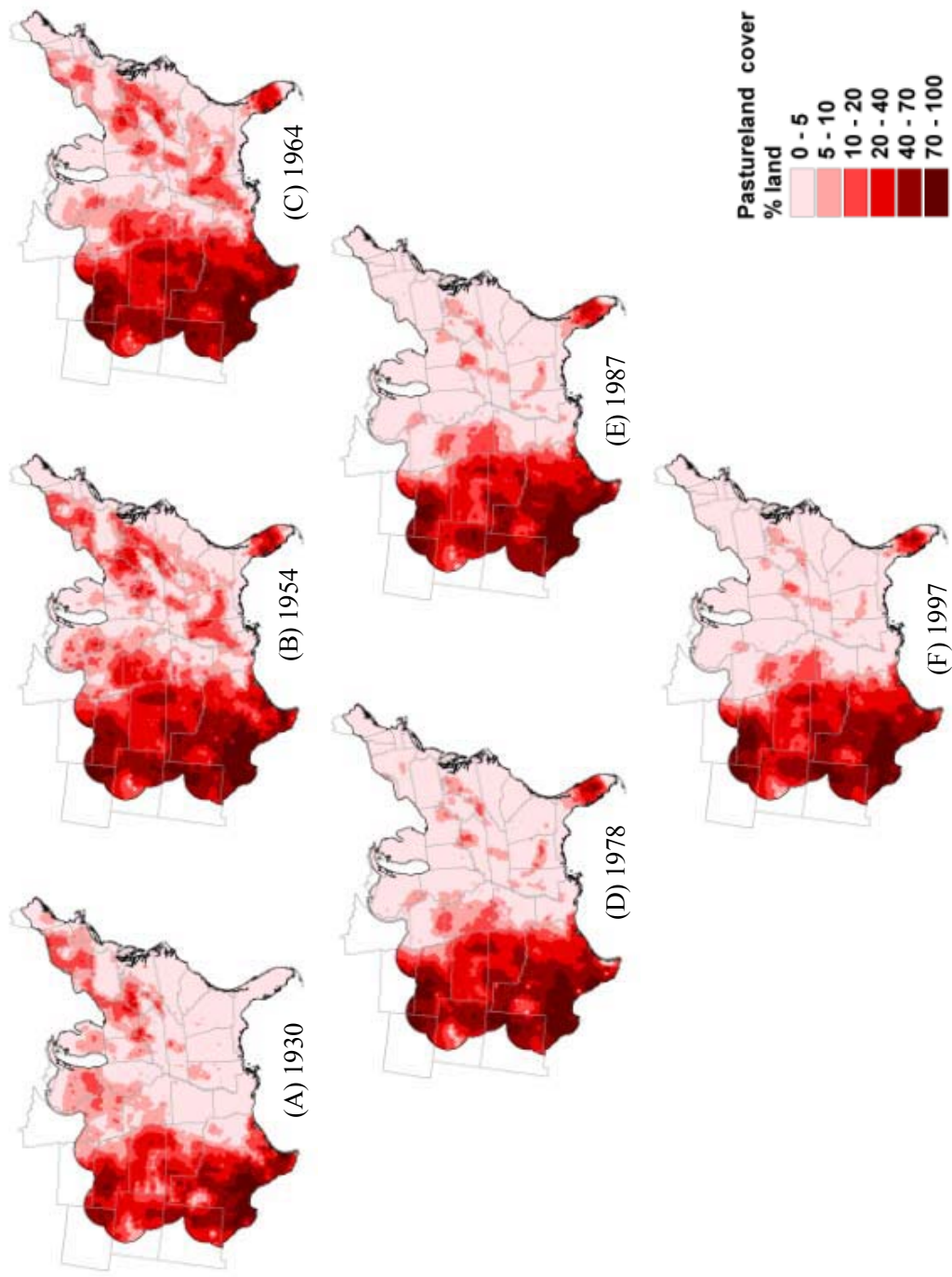


Fig. 3.23. Pastureland other than cropland and woodland in the northern bobwhite range, 1920-1997

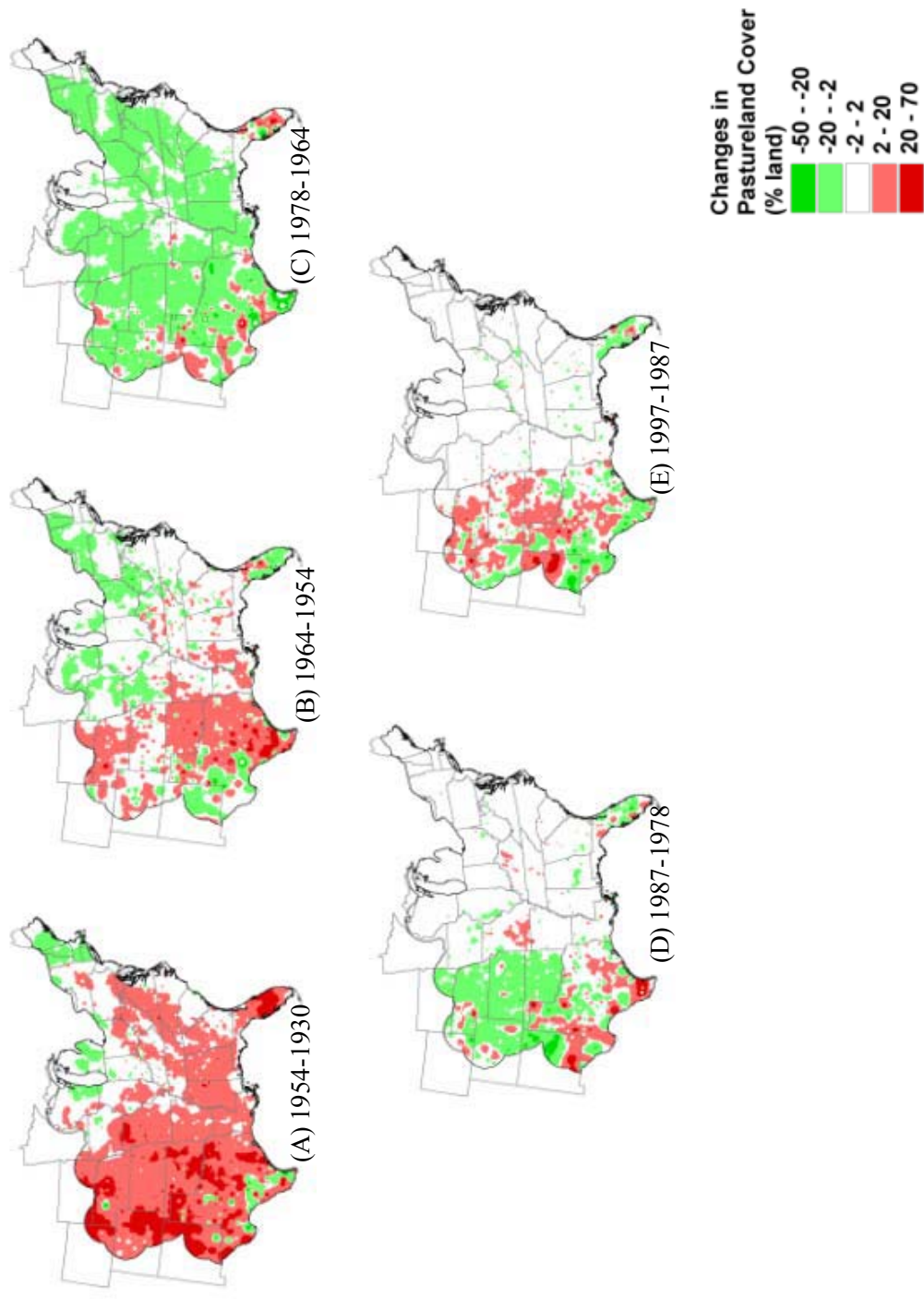


Fig. 3.24. Changes in pastureland other than cropland and woodland cover in the northern bobwhite range, 1920-1997

witnessed severe decline except small portions of Texas, Missouri, Illinois, Ohio, the eastern part of the United States and Lake States. Minor increases were observed in some parts of Texas, Nebraska, and Florida during that period (Fig. 3.24C)

However, from 1978 to 1987 changes were observed only in most parts of the Great Plains and coastal Florida. Very minor increases happened in Missouri, southern and western Texas (Fig. 3.24D). The states showing declining trends in total pastureland in the previous decade, on the other hand, showed rising trends with the exception of the coastal bend of Florida (Fig. 3.24E).

Other land

There were no significant changes from areas designated as “other land” between years 1930 and 1997 (Fig. 3.25). Only in the years between 1930 and 1954, partial losses were observed in the southeastern portions of the NBW range especially in Kentucky, Mississippi, Alabama, Georgia, South and North Carolina. In that decade, the acreage of other land increased in Florida (Fig. 3.26A).

CRP/WRP coverage

Between 1987 and 1997, increases took place in, CRP/WRP Coverage from northern Texas through western Kansas, southern Iowa, and northern Missouri (Fig. 3.27).

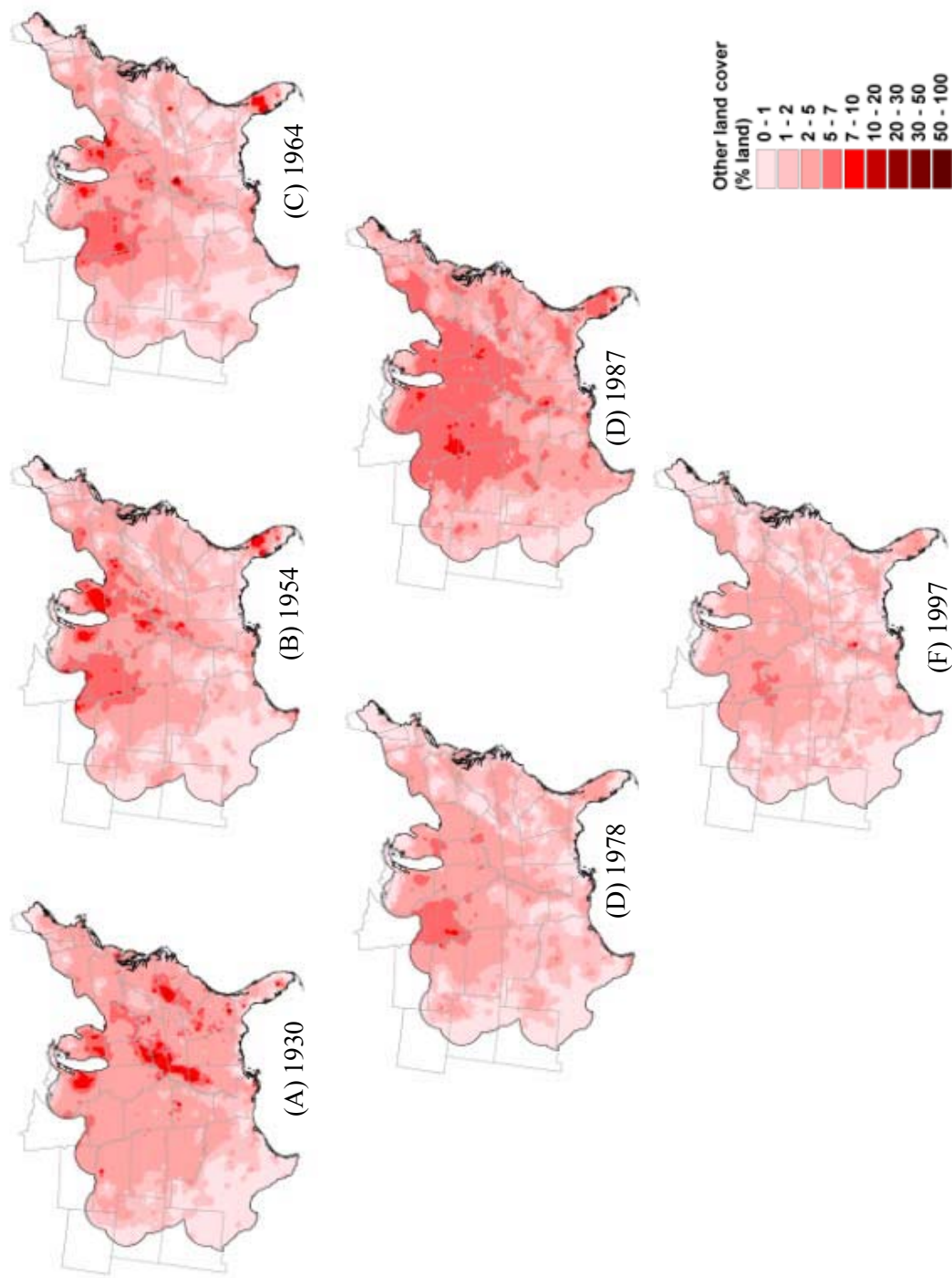


Fig. 3.25. Other land in the northern bobwhite range, 1920-1997

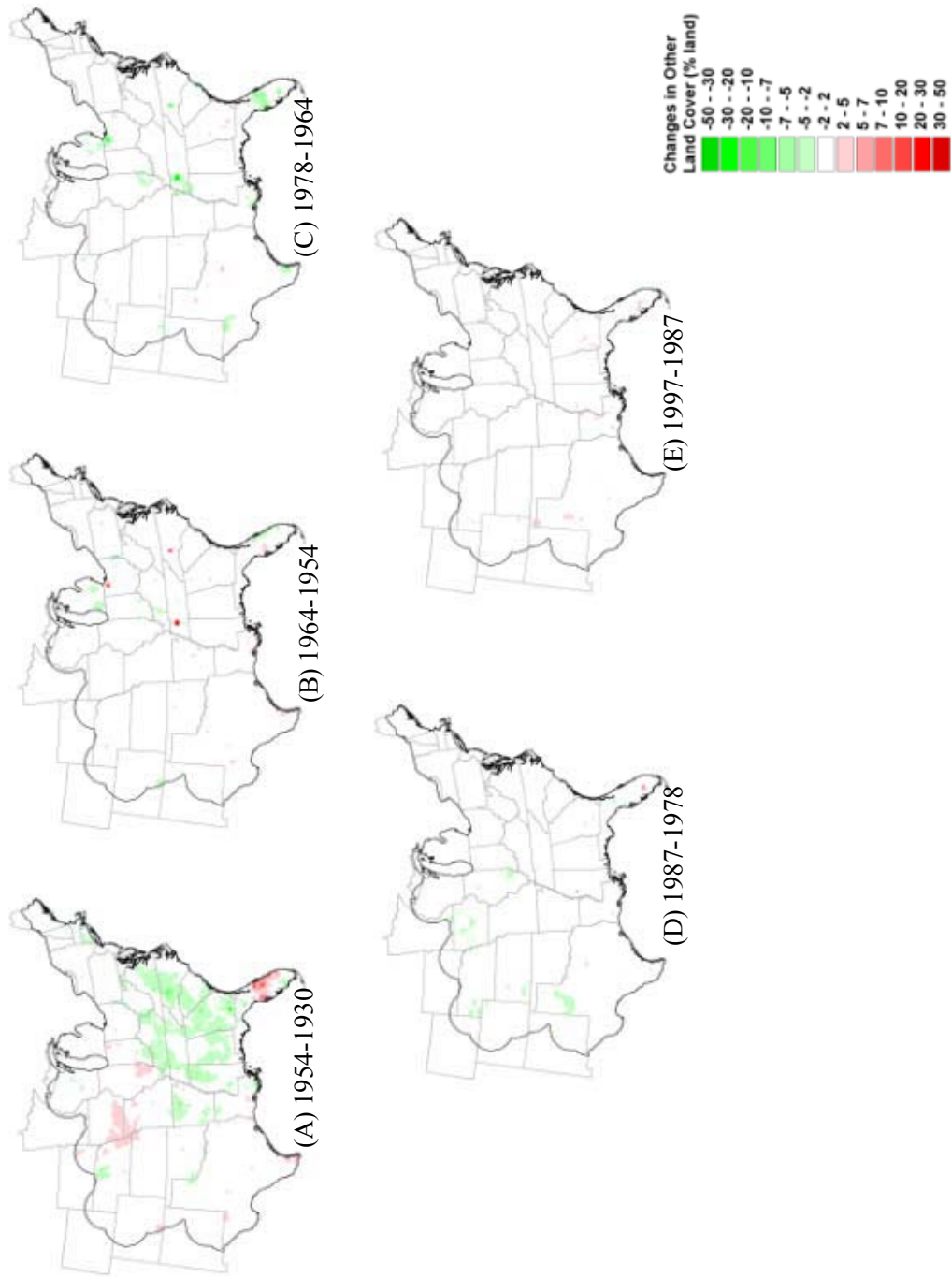


Fig. 3.26. Changes in other land in the northern bobwhite range, 1920-1997

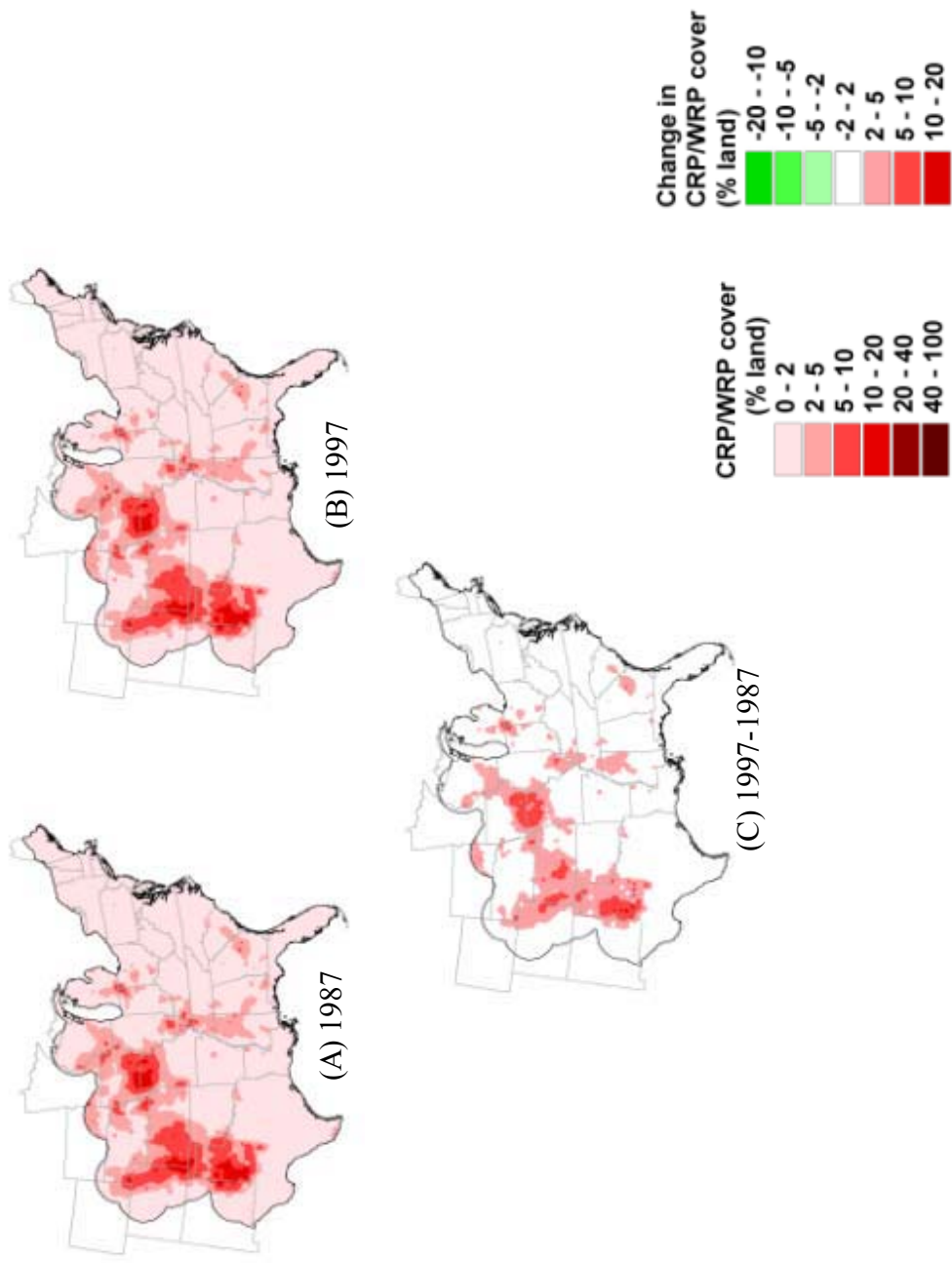


Fig. 3.27. CRP/WRP cover and change in the northern bobwhite range, 1920-1997

Farm density

Farm density declined drastically all over the NBW range between 1920 and 1997 (Fig. 3.28). This decline was noted in most portions of the range, except some parts in Texas, Louisiana, Mississippi and along the Mississippi River from 1920 to 1930 (Fig. 3.29A). Although there were minor increases in density, particularly in Tennessee and Kentucky between 1930 and 1940, significant decreases were observed in the southern parts of the range (Fig. 3.29B). The decline in the farm density also continued between 1940 and 1978 throughout most portions of the NBW range (Fig. 3.29C-E). However, no changes were noted in farm density in the following decades (Fig. 3.29F-G).

Average farm size

Unlike farm density, average farm size showed a continuously increasing trend from 1920 to 1997 (Fig. 3.30). The increases were mostly observed in the western edge of the NBW range between 1920 and 1930 (Fig. 3.31A). In the following decade, average farm size continued to increase in eastern Texas, Oklahoma, Kansas and Iowa and western New Mexico, Colorado and Wyoming (Fig. 3.31B).

The area where average farm size increased in the previous decade extended eastward between 1940 and 1954. Farm sizes also increased in Florida in the same period (Fig. 3.31C). From 1954 to 1964, some increases were experienced along the Mississippi River, besides the eastern portion of the NBW range (Fig. 3.31D). Between 1964 and 1978, farm size expanded mostly in northeastern Texas, western New Mexico and along the Mississippi River (Fig. 3.31E). Insignificant increases were observed in NBW range from 1978 to 1997 (Fig. 3.31F-G).

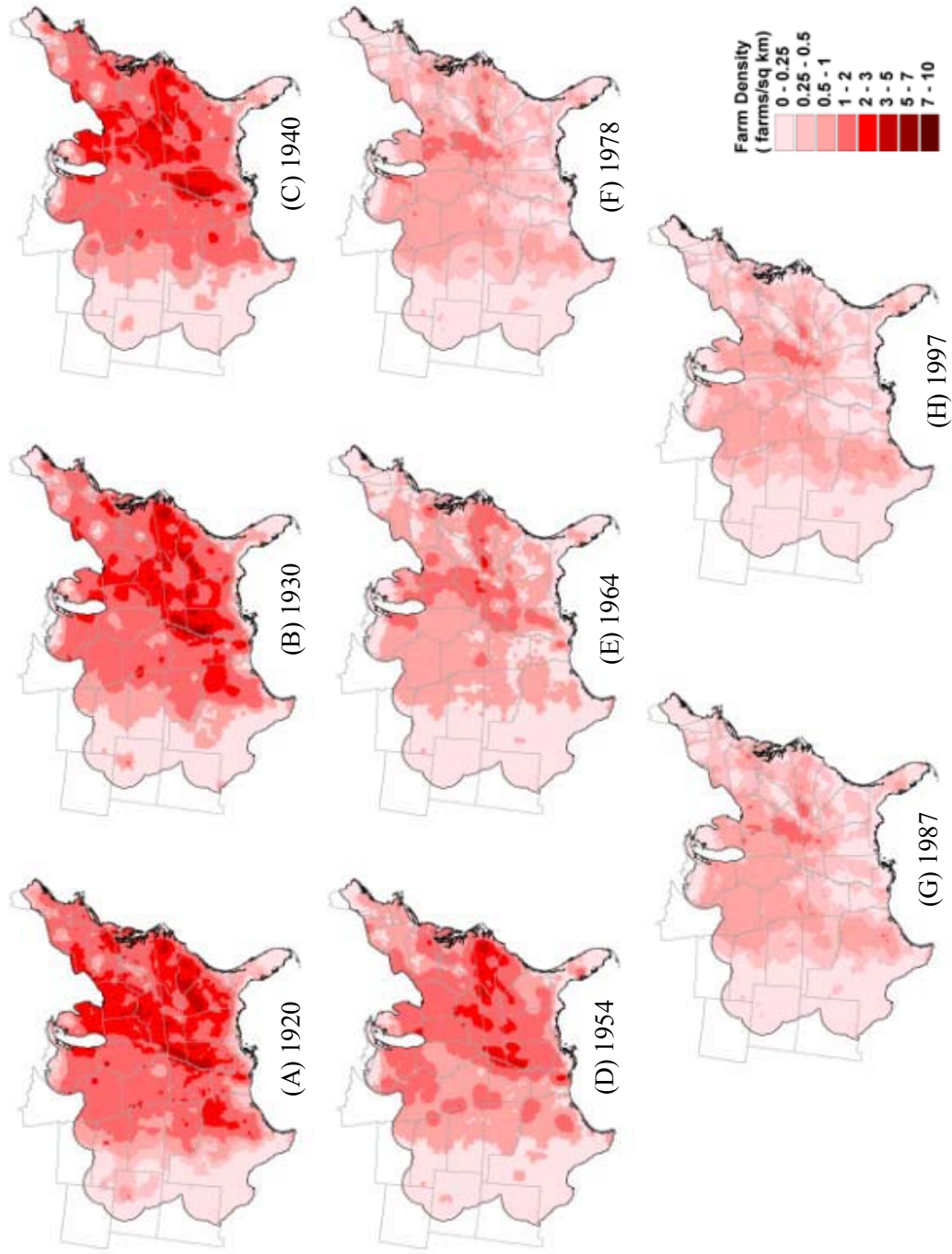


Fig. 3.28. Farm density in the northern bobwhite range, 1920-1997

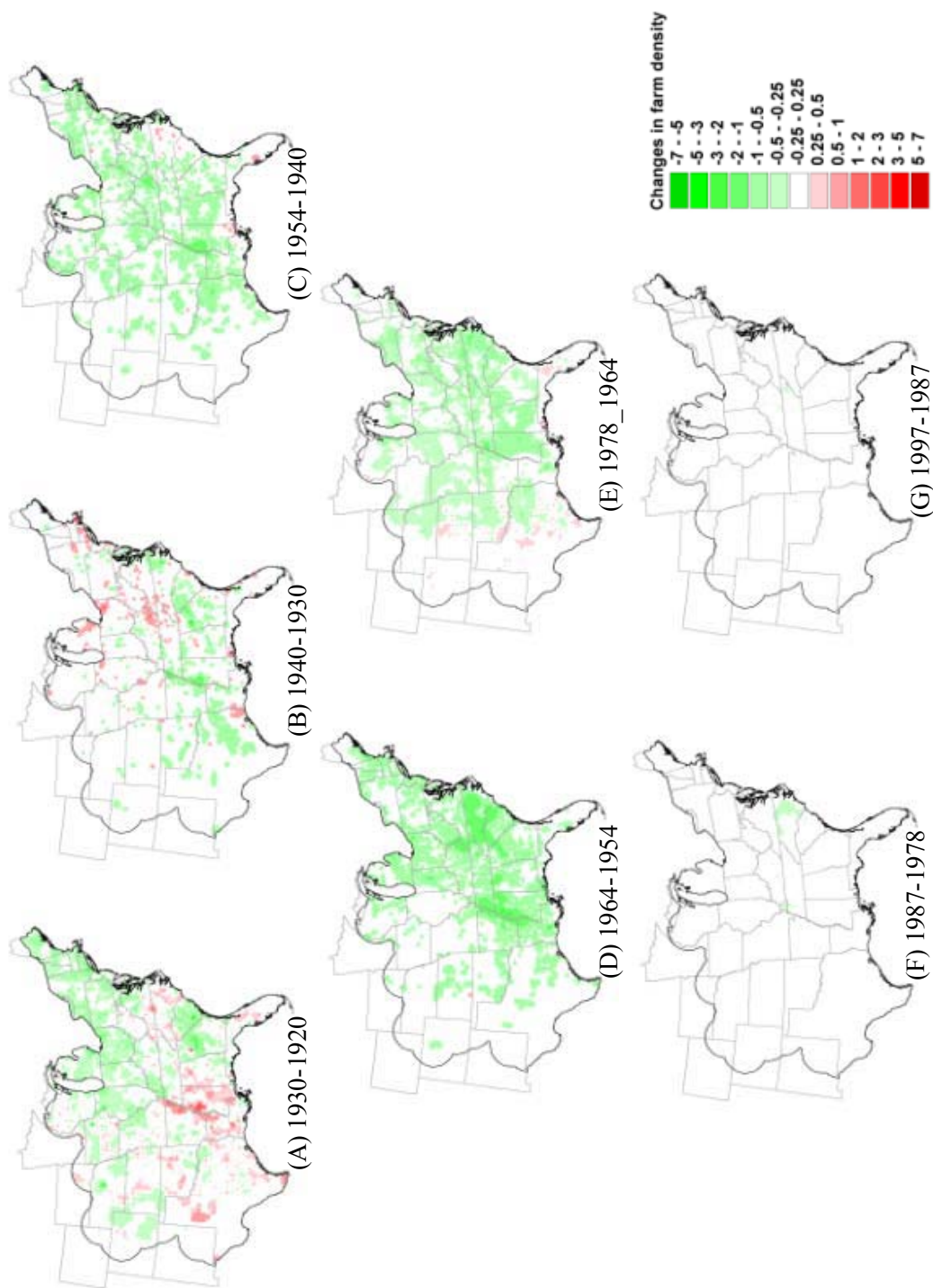


Fig. 3.29. Changes in farm density in the northern bobwhite range, 1920-1997

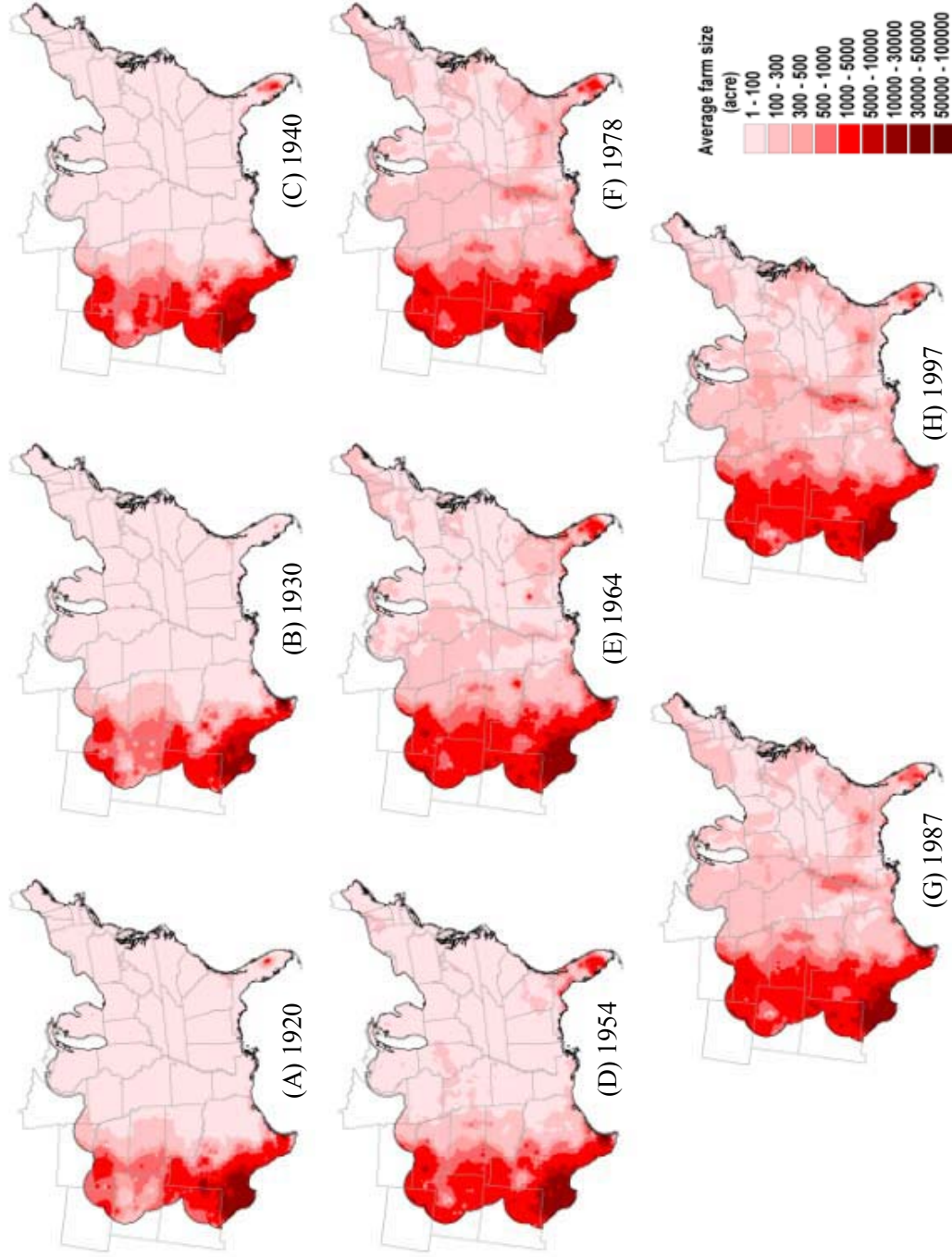


Fig. 3.30. Average farm size in the northern bobwhite range, 1920-1997

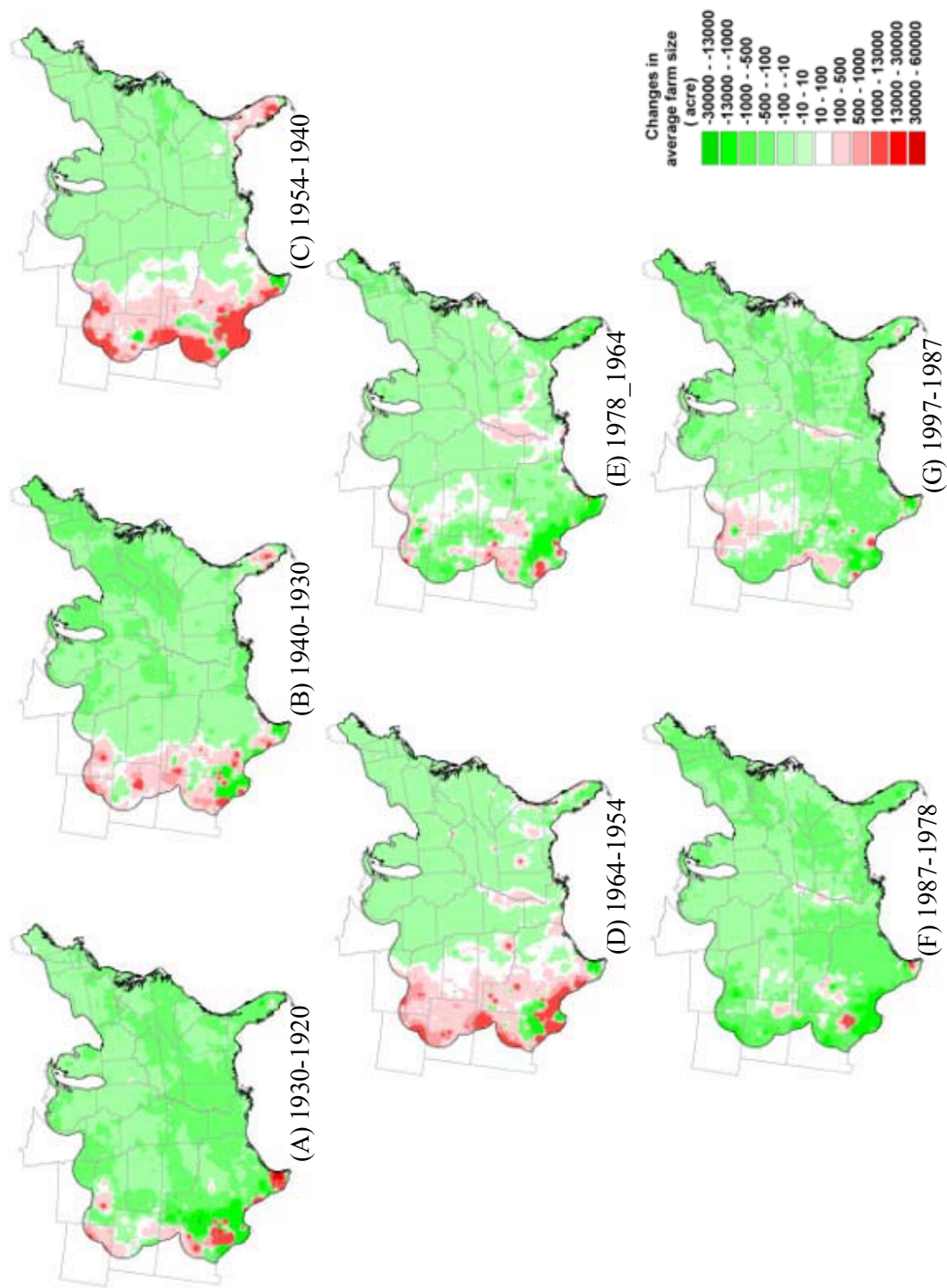


Fig. 3.31. Changes in average farm size in the northern bobwhite range, 1920-1997

Changes in Crops

Corn

There has been a clear change in corn cultivation practices from 1920 through 1997. This can be seen in the intensification of corn cover within the Corn Belt Region. Previously there had been a more diffused but less intense cultivation of corn (Fig. 3.32). Between the years of 1920 and 1930, the production of corn was boosted in the central states mostly extending from northeastern Oklahoma into northern Kansas, western Nebraska, southern South Dakota, Iowa and Illinois. Meanwhile, partial decreases were experienced in most portions of the southeastern states except in Florida (Fig. 3.33A).

A decade later, the trends in corn coverage was reversed and a sharp increase from 1920 to 1930 was translated into a drastic decrease in the following decade. Similarly, the states experiencing decline in the previous decade witnessed gains between 1930 and 1940. The intense declines happened in Oklahoma, eastern Colorado, Kansas, Nebraska, Iowa, Missouri, and Illinois during that period (Fig. 3.33B). Between 1940 and 1954 corn production diminished in all southeastern states and in the Appalachian Region. Minor augmentation took place in the Corn Belt Region during that decade (Fig. 3.33C). Losses experienced in the same places during the previous years continued to decrease in the decade of 1954 and 1964 (Fig. 3.33D). There were substantially concentrated increases of corn production stretching from Indiana through Nebraska into western Kansas from 1964 to 1978 (Fig. 3.33E). Between 1978 and 1987, considerable and vast decreases happened especially in Iowa, Illinois, and Indiana (Fig. 3.33F). But from 1987 through 1997, the acreages of corn cover were boosted Indiana, Illinois, western Oklahoma, southern Nebraska, and Iowa (Fig. 3.33G).

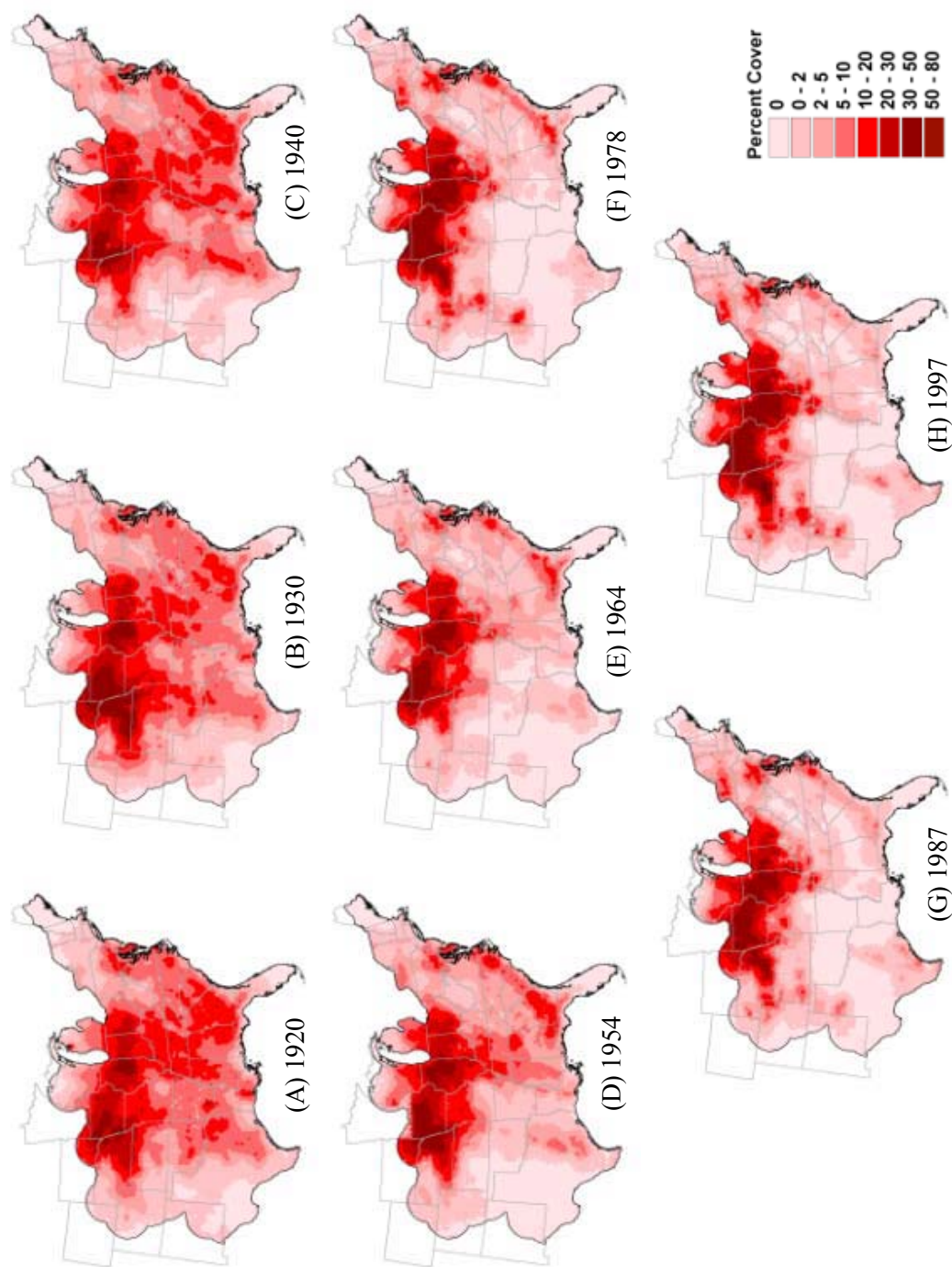


Fig. 3.32. Corn cover in the northern bobwhite range, 1920-1997

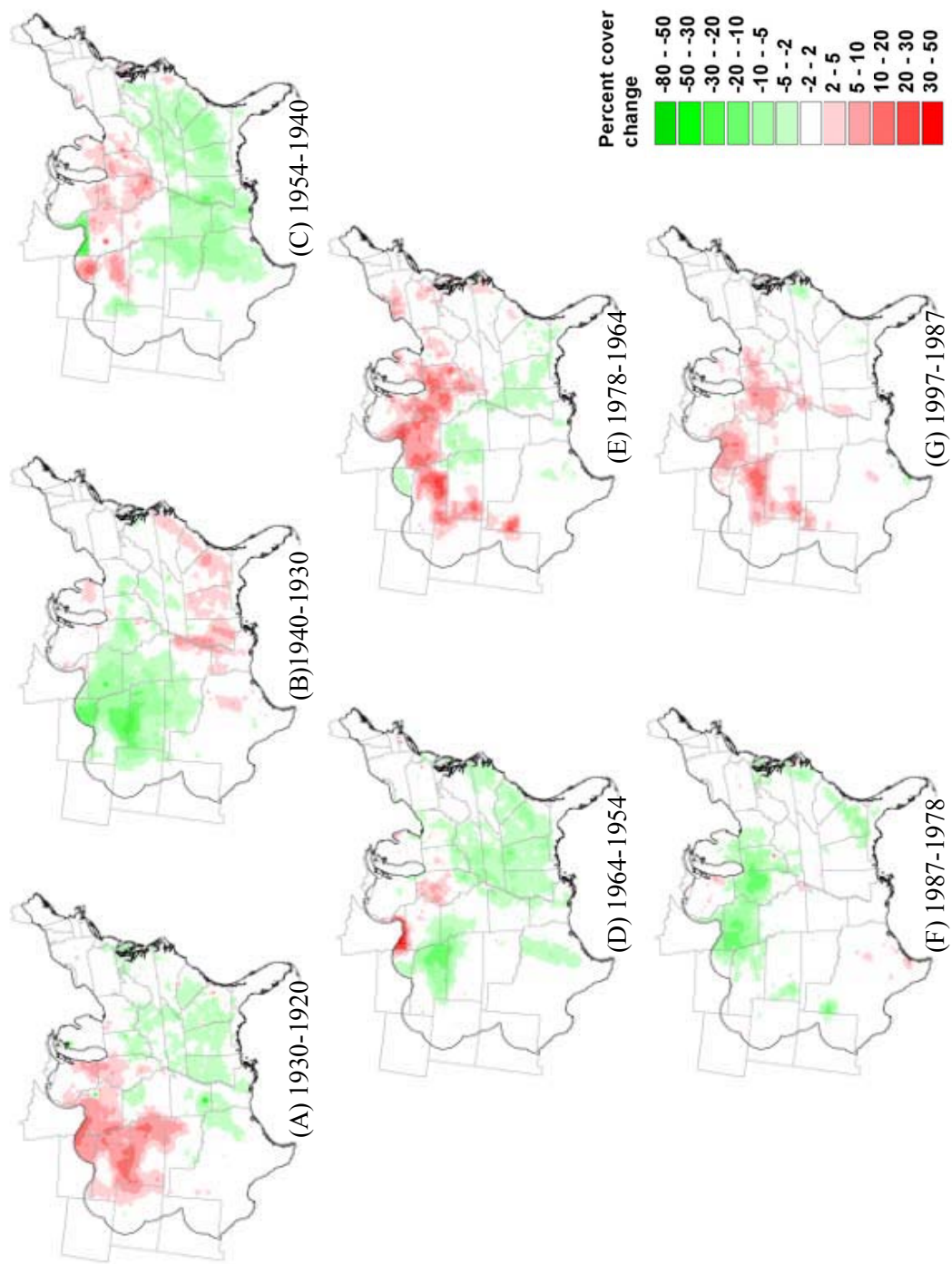


Fig. 3.33. Changes in corn cover in the northern bobwhite range, 1920-1997

Wheat

The trend in wheat production between 1920 and 1997 showed strong continuity of crop yield in the Winter Wheat Region with greater variation of crop cover in other areas within the NBW range (Fig. 3.34). In the decade of the 1920s, intensive gains occurred in northwestern Texas and eastern Kansas, whereas major decreases occurred in Ohio, Illinois, Indiana, Missouri and eastern Kansas (Fig. 3.35A). Between 1930 and 1940, significant losses were observed in northern Texas and Oklahoma and western Kansas. On the other hand, wheat production increased in eastern Kansas in the same decade (Fig. 3.35B).

From 1940 through 1954, much of eastern Kansas witnessed a slight reduction in the production of wheat. In the meantime, minor increases were seen in northern Texas and western Kansas (Fig. 3.35C). In 1954, very few losses and gains were observed all over the NBW range. The decrease occurred on the Oklahoma-Kansas border, while gains took place along the Mississippi River (Fig. 3.35D).

In the years between 1964 and 1978, losses occurred more often stretching from eastern Kansas through Missouri into Illinois, Indiana, Ohio, and Wisconsin. Meanwhile, a few spots showed an increasing trend along the Colorado-Kansas border and that of Kansas-Arkansas (Fig. 3.35E). Between 1978 and 1987, no significant changes in wheat cover occurred except for decreases in Oklahoma and Kansas and an increase along the Mississippi River (Fig. 3.35F). From 1987 through 1997, the situation was mostly stable like in the previous decade. Primarily Oklahoma witnessed slight increases in wheat production at that time (Fig. 3.35G).

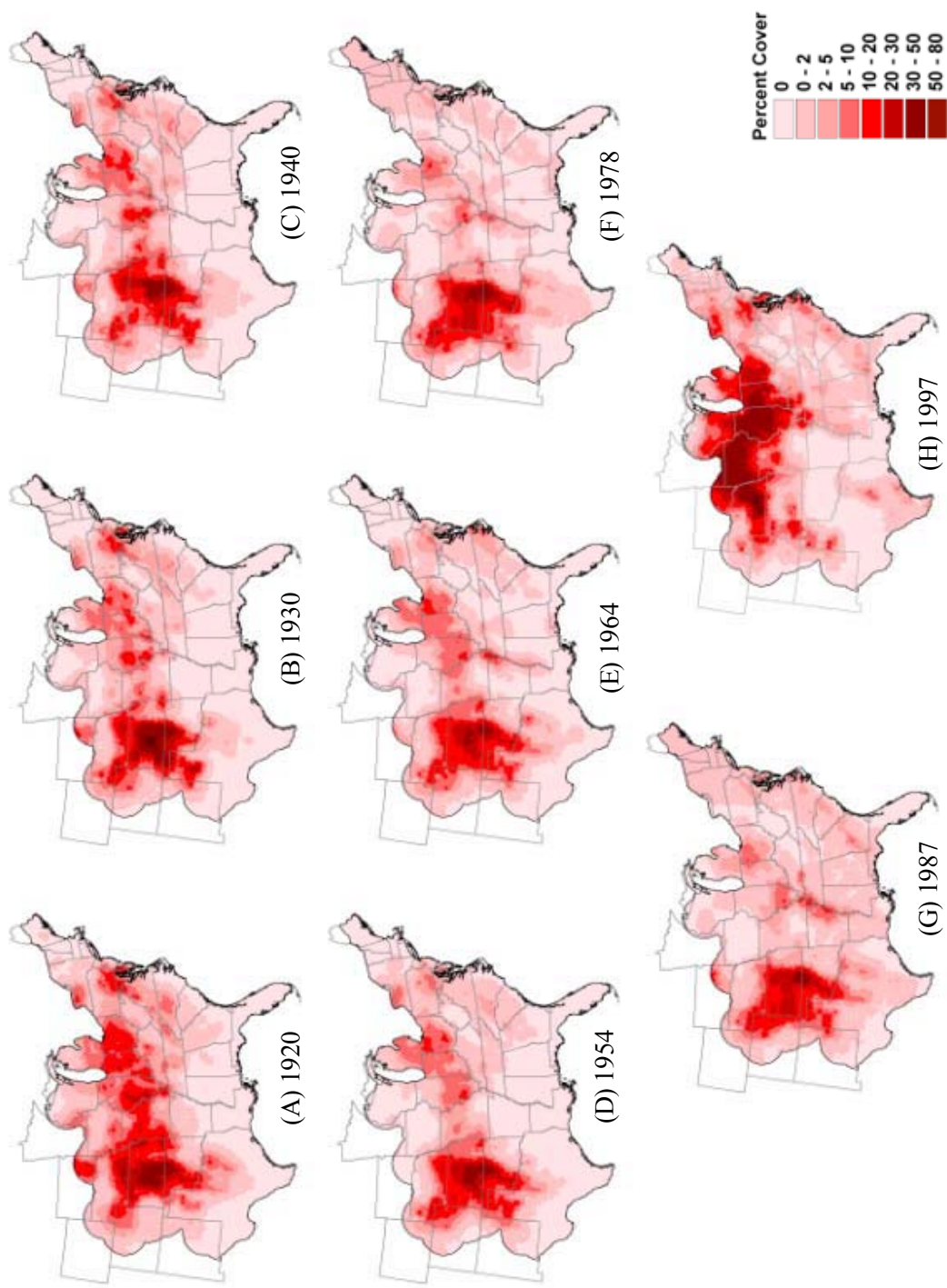


Fig. 3.34. Wheat cover in the northern bobwhite range, 1920-1997

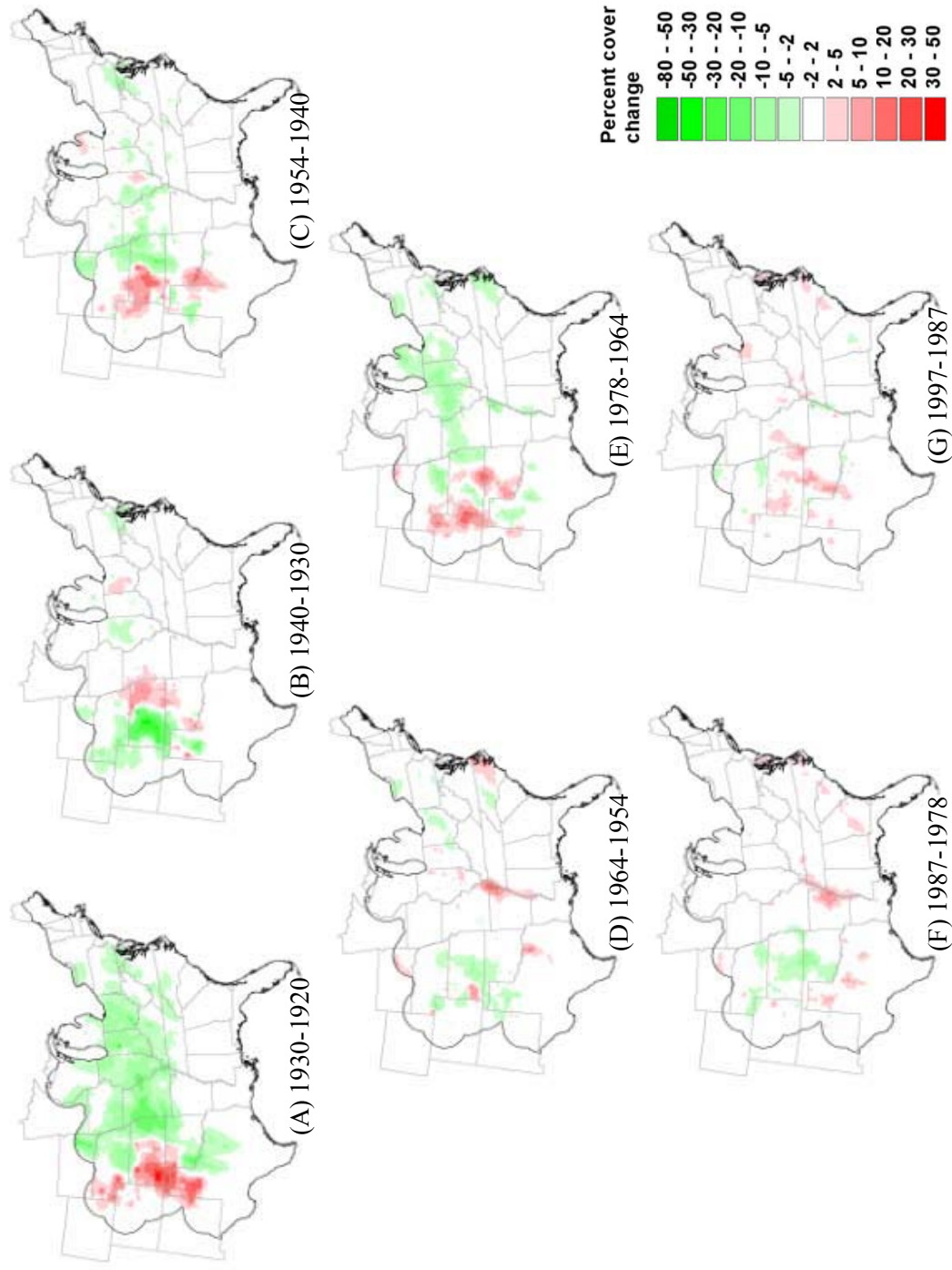


Fig. 3.35. Changes in wheat cover in the northern bobwhite range, 1920-1997

Sorghum

Sorghum production showed a quite consistent pattern over the seventy-year period (Fig. 3.36). In 1930s, partial increases occurred in Texas, Kansas, Nebraska and South Dakota (Fig. 3.37A). Between 1940 and 1954 the increase in the acreages of sorghum extended from northern Texas and Oklahoma through Kansas and into Nebraska. There had been slight gains in southern Texas. Meanwhile, the decreases in production were observed in South Dakota, western Texas and Oklahoma (Fig. 3.37B). From 1954 to 1964 experienced increases in southern Nebraska, whereas severe losses occurred in the western Texas, Oklahoma, and Kansas (Fig. 3.37C).

Between 1964 and 1978, very small increases were seen on the Kansas-Nebraska border. During that decade, significant decline were observed in the Texas panhandle, western Oklahoma, Kansas and eastern Nebraska. Considerable gains did not occur during the following two decades (Fig. 3.37D). From 1978 through 1987, much of the decline in sorghum cover was seen along a narrow belt in Texas stretching from near Corpus Christi to the Oklahoma border and the northern region of the Texas panhandle. Some losses were also observed in Kansas and Nebraska during the same period (Fig. 3.37E). In the following decade, the Kansas-Nebraska border experienced another slight loss (Fig. 3.37F).

Hay

In the 1920s, there was dense hay coverage in the north central region of the United States extending into the northeast. Over time, hay coverage has diminished and by the end of the century one can only find extensive coverage along the central corridor

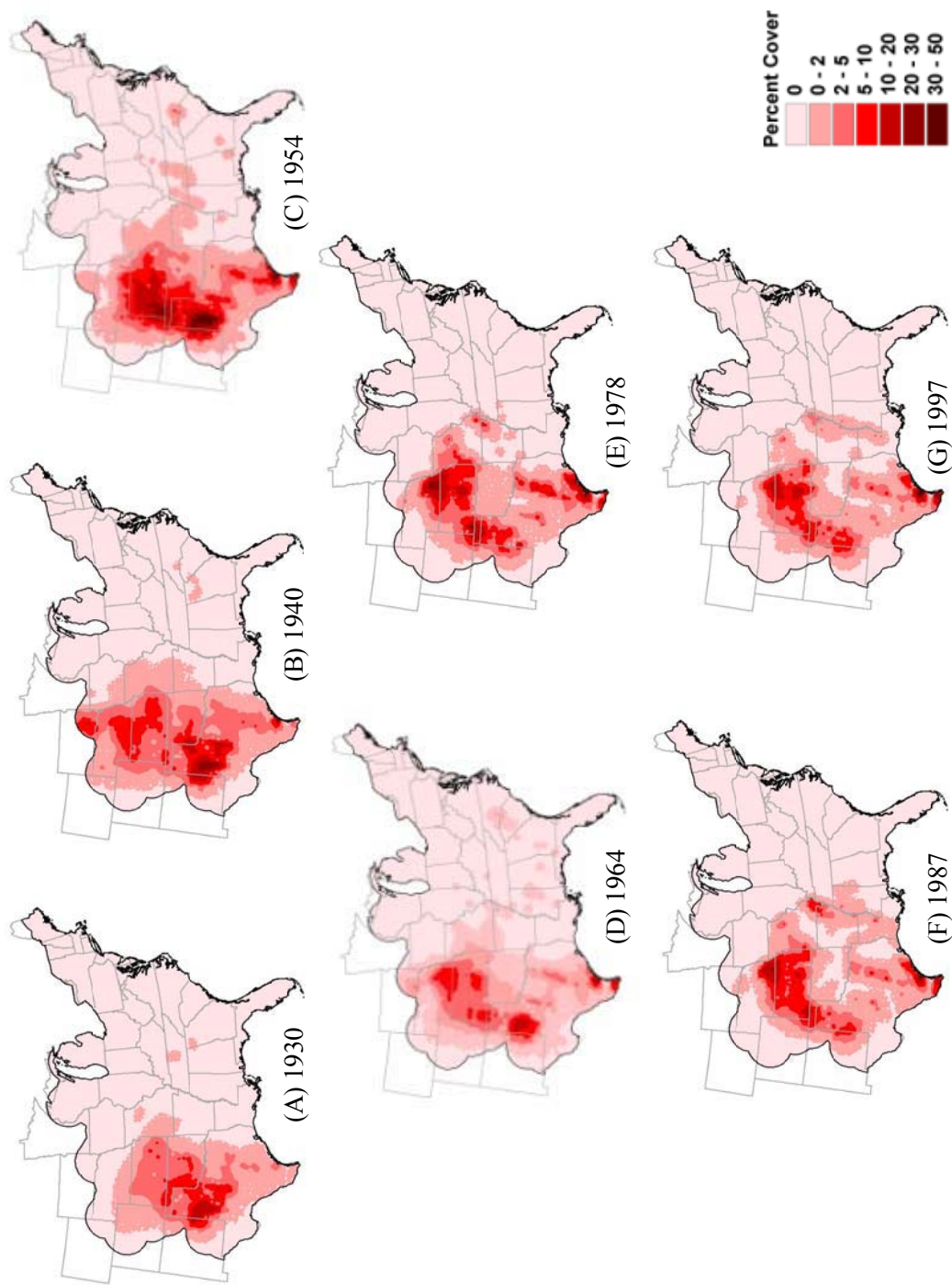


Fig. 3.36. Sorghum cover in the northern bobwhite range, 1920-1997

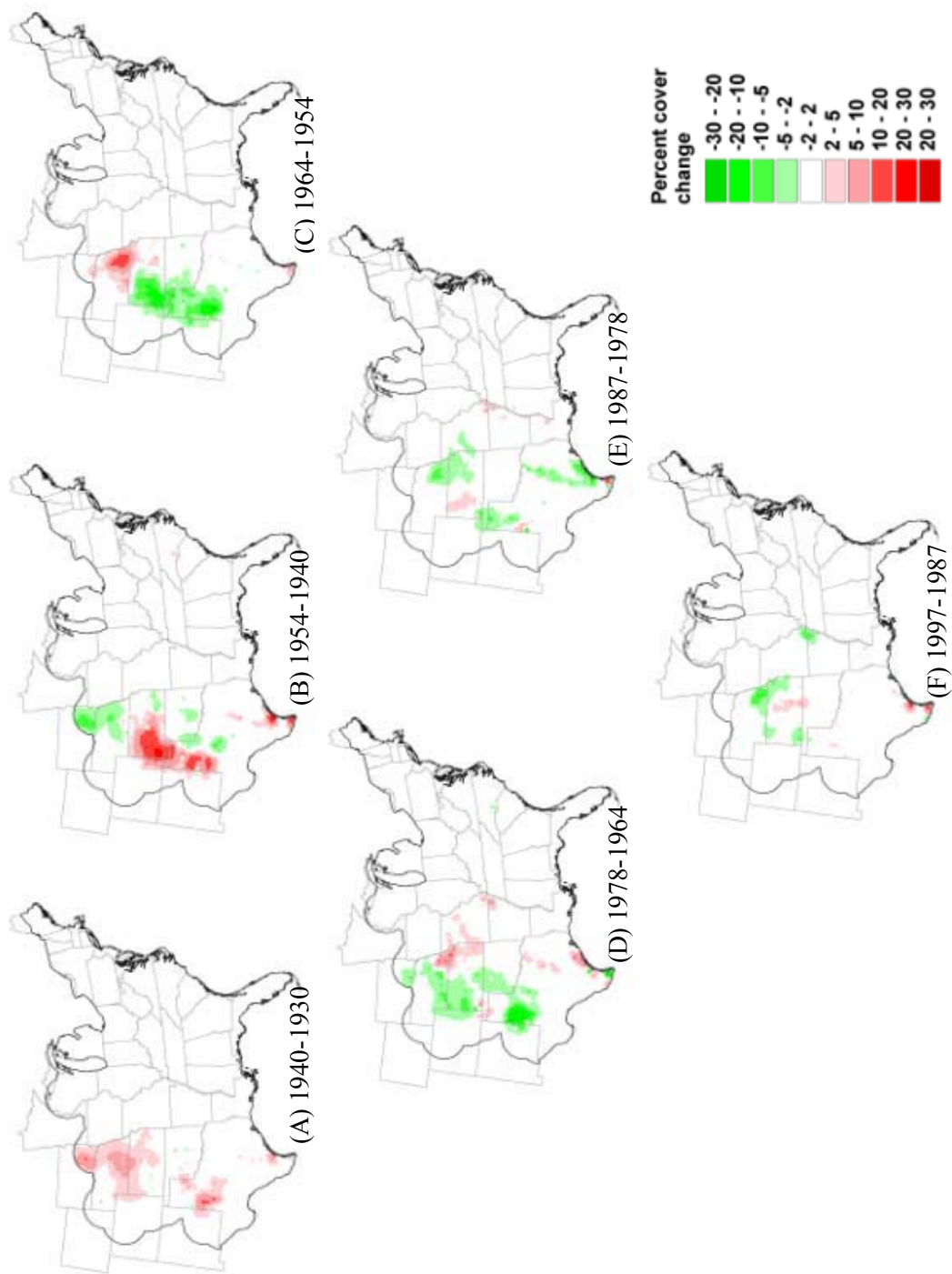


Fig. 3.37. Changes in sorghum cover in the northern bobwhite range, 1920-1997

extending from Texas north through Wisconsin (Fig. 3.38). The acreage of hay production declined severely from 1920 to 1930. There was a wide-range diffusion of hay cover from the mid to higher latitude of the NBW range (Fig. 3.39A).

However, decline in hay production lessened in the 1930s, particularly in South Dakota, eastern Nebraska, Kansas and northern Missouri. In the same decade some gains were observed along the Mississippi River, on the Alabama-Tennessee border, in southwestern Georgia, in South Carolina and North Carolina (Fig. 3.39B). In contrast to the previous decade, the regions which showed an increase in hay coverage experienced decreases between 1940 and 1954. In addition, during those years some places in the southeastern portions of the NBW range witnessed some losses. In the meantime, hay acreage grew significantly from Kansas through South Dakota (Fig. 3.39C).

Between 1954 and 1964 a line of losses stretching from Nebraska in the west to Ohio in the east was observed (Fig. 3.39D). The declines in the same area continued until 1978. There had been slight increases in Wisconsin, southwestern Missouri and eastern Texas from 1964 to 1978 (Fig. 3.39E). In the following decade, almost no changes were experienced in hay cover except for mild losses in northern Nebraska and South Dakota, and a small gain in Kentucky (Fig. 3.39F). In the decade of 1987s most states remained unchanged while Wisconsin saw minor losses and northeastern Texas and Oklahoma had partial increases in hay production (Fig. 3.39G).

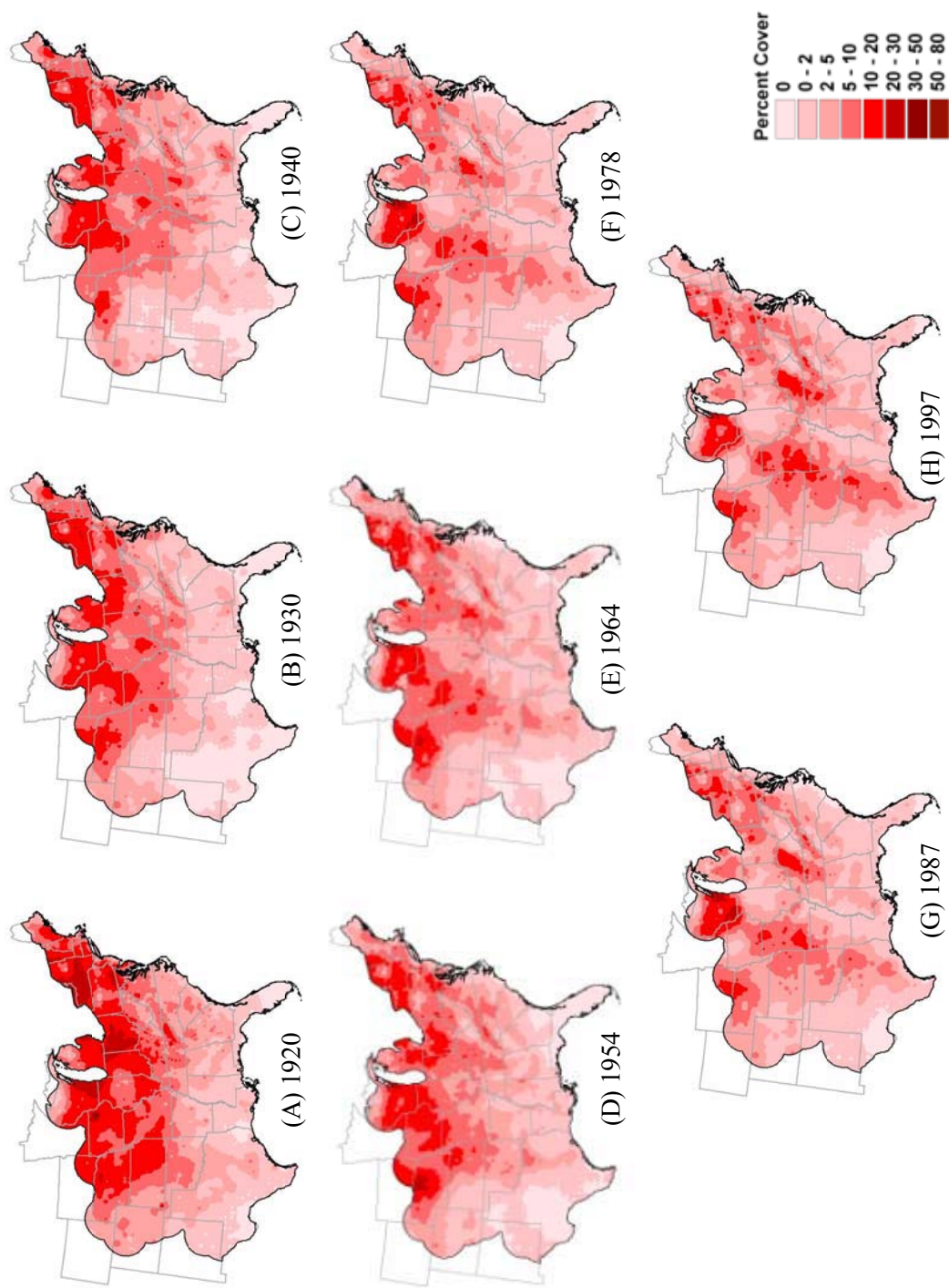


Fig. 3.38. Hay cover in the northern bobwhite range, 1920-1997

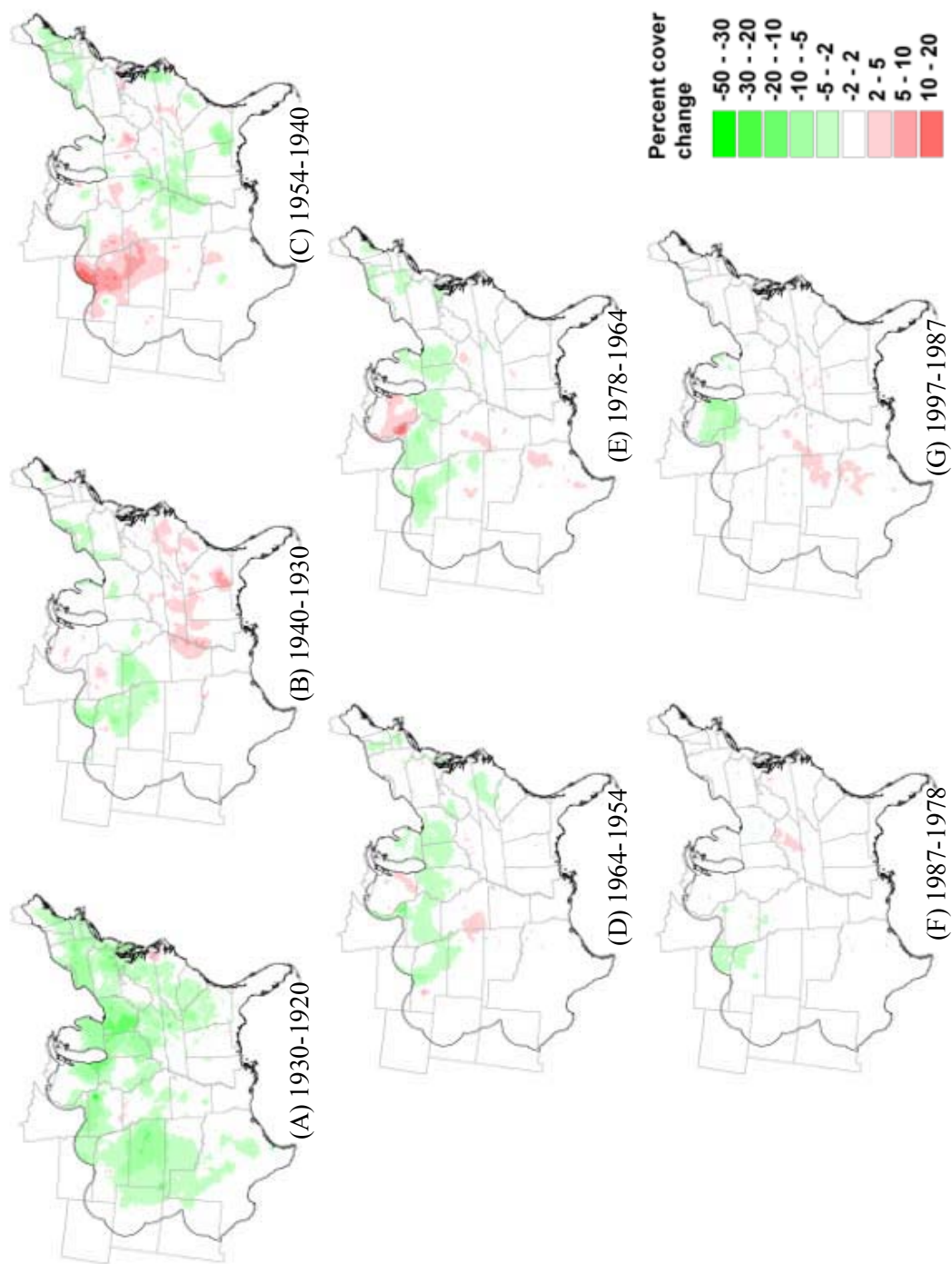


Fig. 3.39. Changes in hay cover in the northern bobwhite range, 1920-1997

Cotton

There was a continuous loss of cotton production beginning in the 1930s through the end of the century. The changes in cotton production through all these years took place in the southern and southeastern parts of the NBW range, known as the Cotton Belt (Fig. 3.40). In the decade of the 1920s, intense increases in cotton coverage were experienced in the states stretching from eastern Texas to the Mississippi River, and into Alabama. In addition, considerable changes were observed in the Texas panhandle and southwestern Oklahoma. Meanwhile, cotton production showed a decline in southern Oklahoma, Georgia and South Carolina (Fig. 3.41A).

The following decade was a period where almost all southern states except for Florida and some parts of eastern Texas experienced wide-range and intense declines (Fig. 3.41B). The losses in cotton production continued between 1940 and 1954 in the same region though they were not as intense or extended. During these years slight gains were observed in southern and eastern Texas, whereas cotton production remained stable in central Texas (Fig. 3.41C). Even though no increase was observed in the acreage of total cotton production in the decade of 1954s, the rate of decline was not as severe as in the previous decades. The losses occurred in this decade in the Texas panhandle and eastern Texas, along the Mississippi River, and in the upland and piedmont regions of the southeast (Fig. 3.41D).

Between 1964 and 1978 the situation hardly changed and declines continued in parts of the southern states. The acreage of cotton production diminished along the Coastal Plains during these years. However, an intense increase was experienced in the Texas panhandle (Fig. 3.41E). The same area witnessed losses in the following decade.

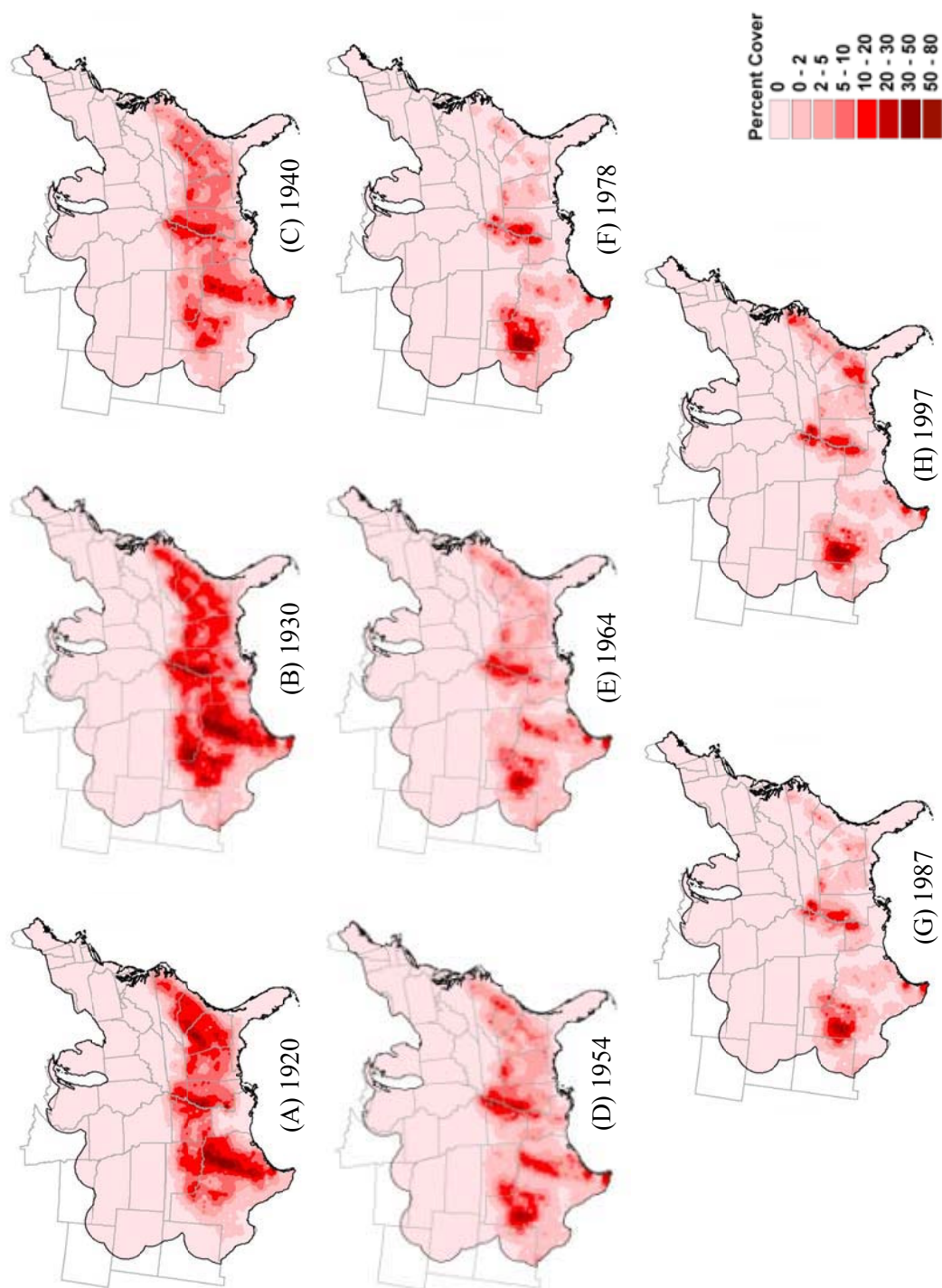


Fig. 3.40. Cotton cover in the northern bobwhite range, 1920-1997

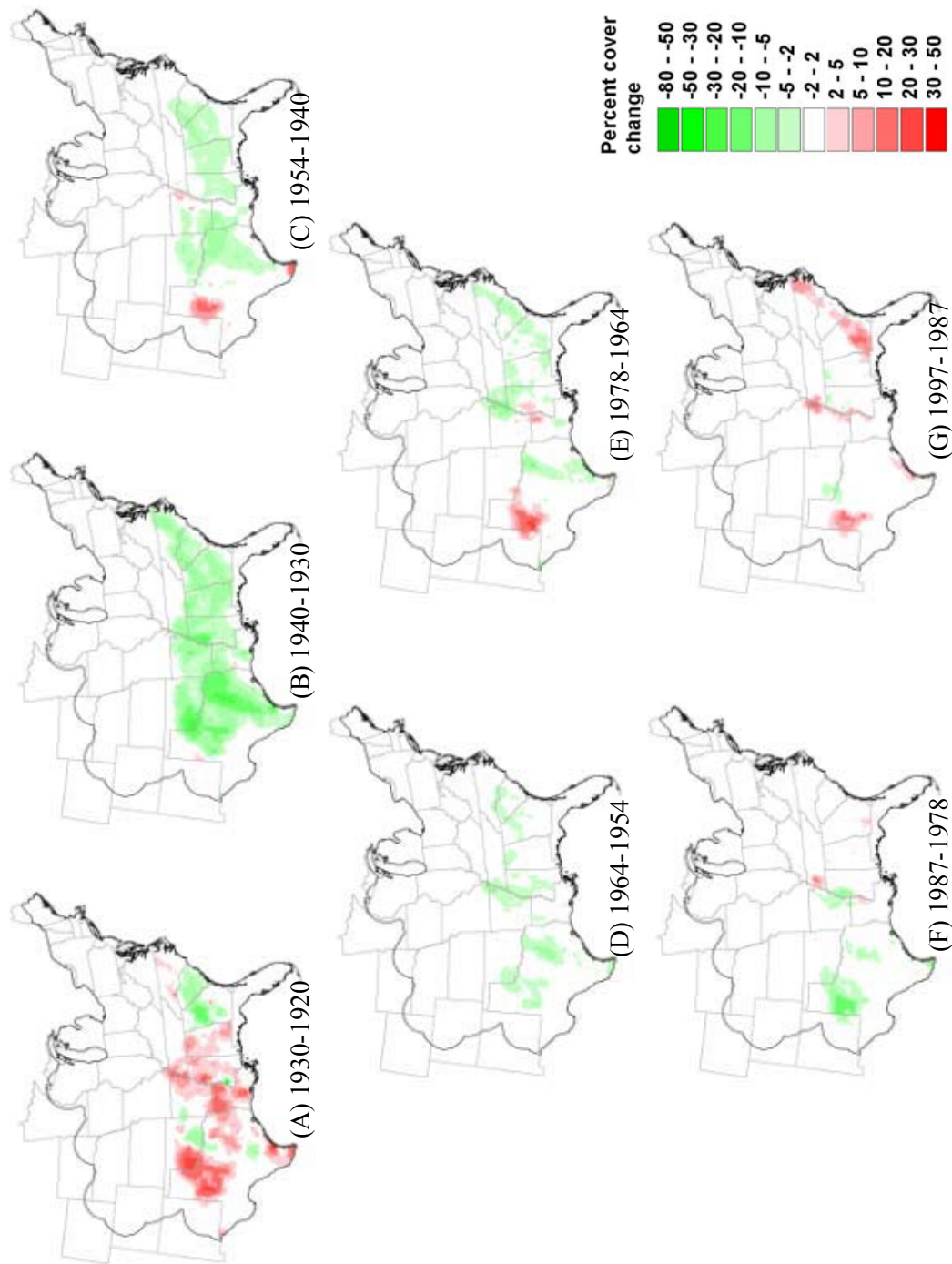


Fig. 3.41. Changes in cotton cover in the northern bobwhite range, 1920-1997

During the same decade, minor decreases happened along the Mississippi River and in the Texas panhandle (Fig. 3.41F). From 1987 to 1997, a significant increase was observed in cotton production. These gains took place in the Texas panhandle, along the Mississippi River, and in the Coastal Plains (Fig. 3.41G).

Soybean

There has been a substantial explosion in soybean production throughout the NBW range since the 1930s (Fig. 3.42) which had its precedence established in the decade of 1920s (Fig. 3.43A). The acreage of soybean production increased intensively between 1930 and 1954. The increases stretched from South Dakota, through Iowa, and Missouri, into Illinois, Indiana, and Ohio. In addition, soybean cover was augmented along the Mississippi Valley and the Kansas-Missouri border during these years (Fig. 3.43B).

The following decade experienced patterns similar to those of the previous year (Fig. 3.43C). From 1964 through 1978, the acreages producing soybean expanded intensively. These expansions covered not only those states that experienced gains during the previous years, but also the states located in the south-central and southeastern portions of the NBW range, except for most of Texas, Arkansas, Florida, Georgia, and Tennessee (Fig. 3.43D).

However, from 1978 through 1987, soybean production diminished in the same places it that flourished earlier: along the Mississippi Valley and coastal plains of the south and southeastern. In the meantime, an area encompassing portions of eastern Nebraska, northern Kansas and eastern Iowa experienced a raise in soybean production

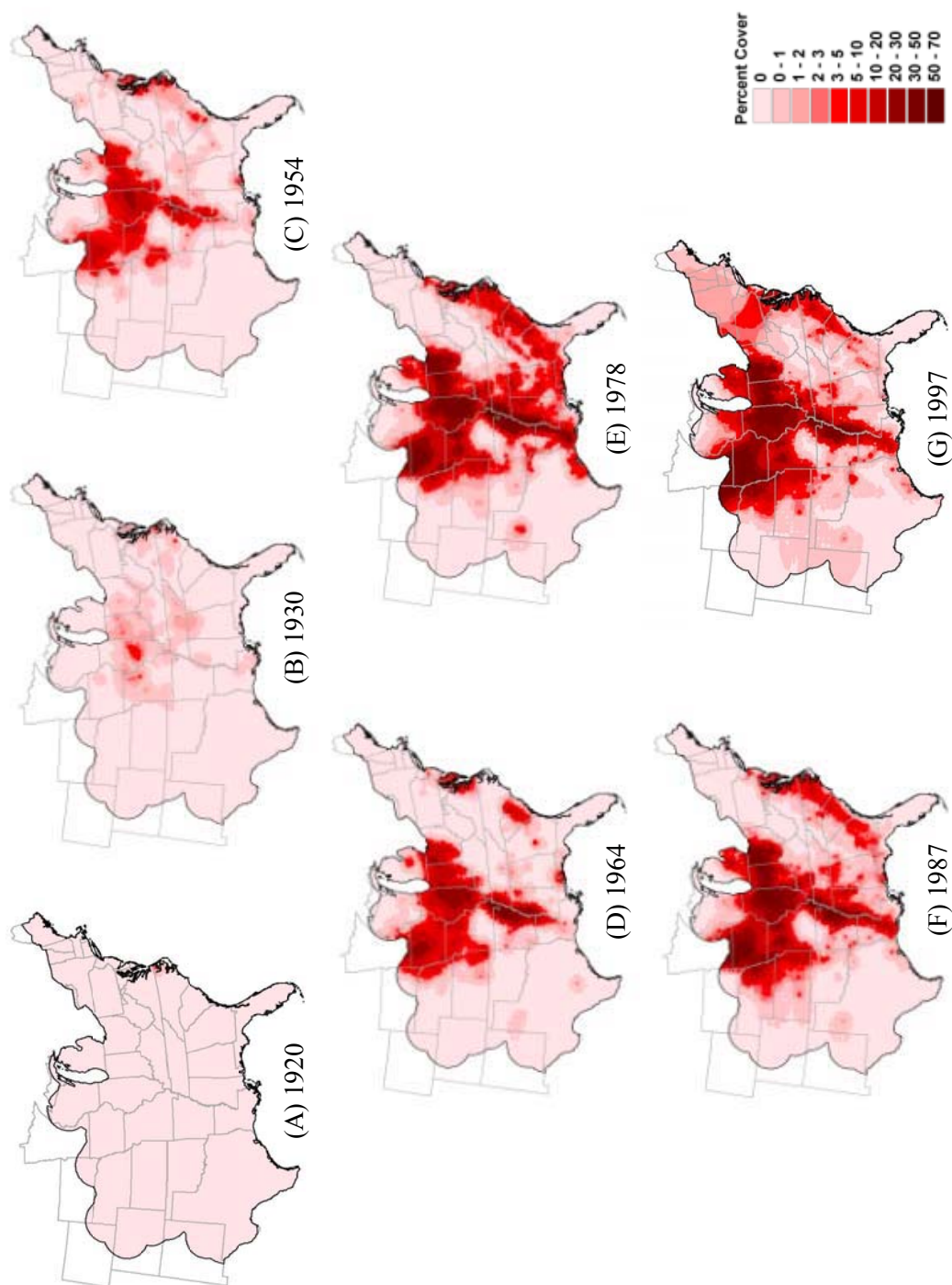


Fig. 3.42. Soybean cover in the northern bobwhite range, 1920-1997

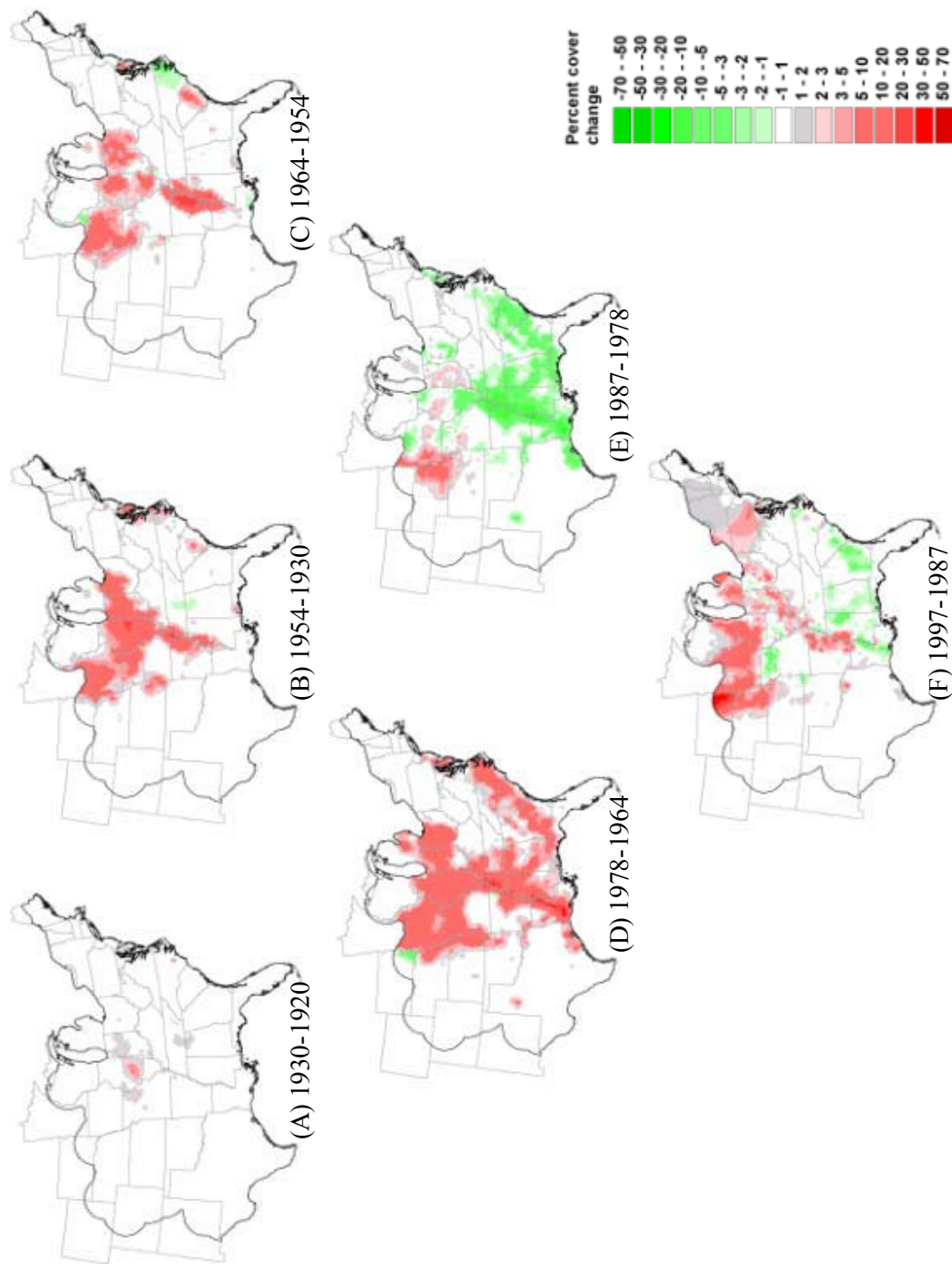


Fig. 3.43. Changes in soybean cover in the northern bobwhite range, 1920-1997

(Fig. 3.43E). In the decade of 1980s many of the losses were terminated, and there was an increase in soybean cover, which took place in the states extending from eastern Nebraska, through Illinois and Michigan. Also, during this decade, partial gains in soybean production were observed scattered along the Mississippi Valley through Pennsylvania (Fig. 3.43F).

Oats

Production of oats in the NBW range declined so severely since the 1920s that it remained a viable crop in very few places by the 1990s (Fig. 3.44). The greatest decrease was noted between 1920 and 1930 in Wisconsin, Illinois and along the Nebraska-Iowa border, extending through Oklahoma and Texas (Fig. 3.45A). Oats cover losses continued in the decade of the 1930s, particularly in the area covering eastern Nebraska, South Dakota, and Iowa. Other losses occurred over this entire period in much of Illinois, Indiana, and Ohio. Meanwhile, few places experienced gains in oats cover, southern Minnesota and the Oklahoma-Kansas-Missouri border (Fig. 3.45B).

Between 1940 and 1954, the acreage of oat cover declined along a stretch of land bordering Texas, Oklahoma, Nebraska, and Missouri. In the same period, a significant increase was observed in South Dakota, eastern Nebraska and western Iowa (Fig. 3.45C). From 1954 to 1964, severe and dramatic decreases were seen in oat production in most areas extending from central Texas, through South Dakota, all the way to New York and Pennsylvania. In addition, much of North Carolina, South Carolina and Georgia experienced losses in the same decade (Fig. 3.45D).

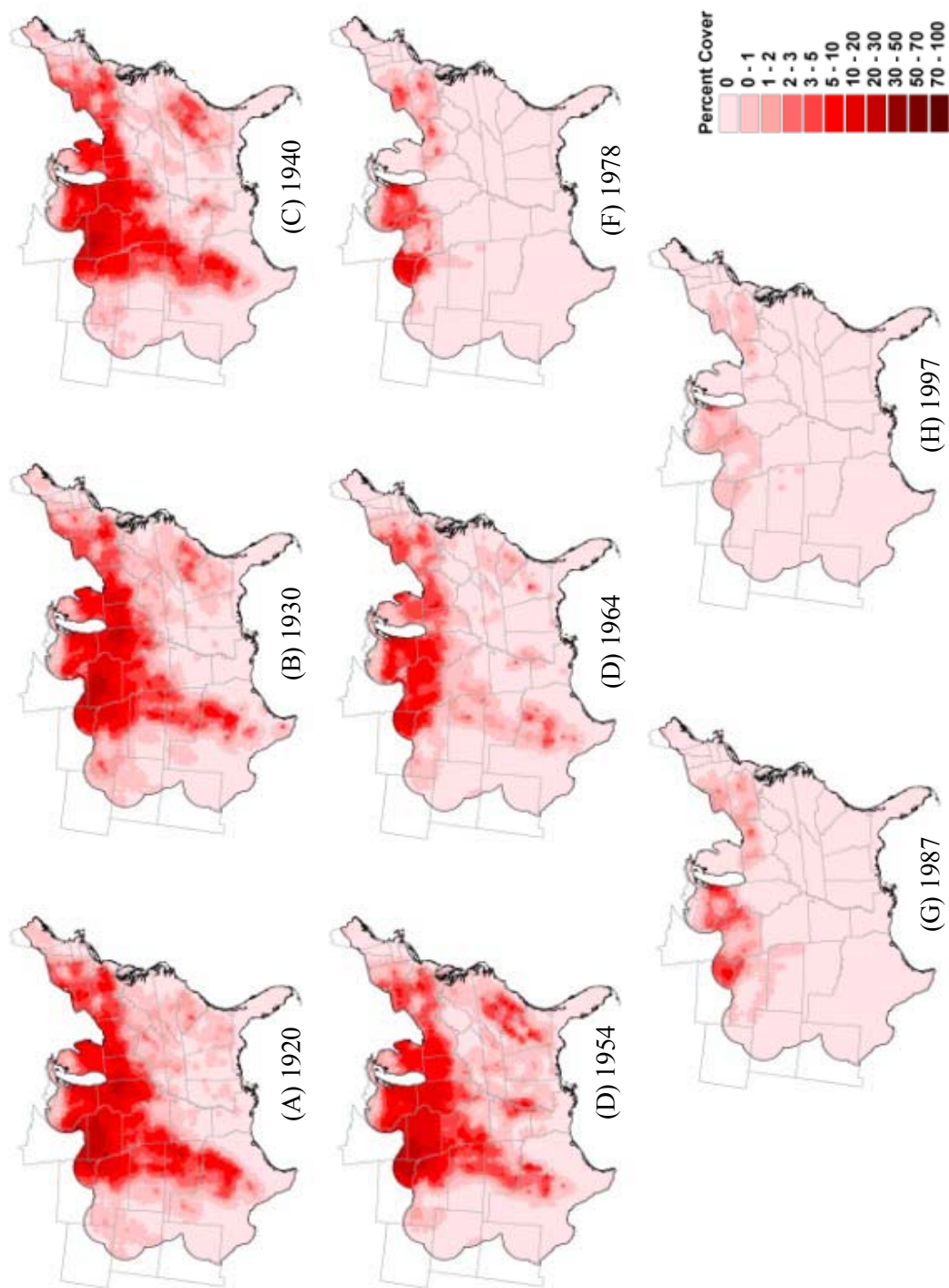


Fig. 3.44. Oats cover in the northern bobwhite range, 1920-1997

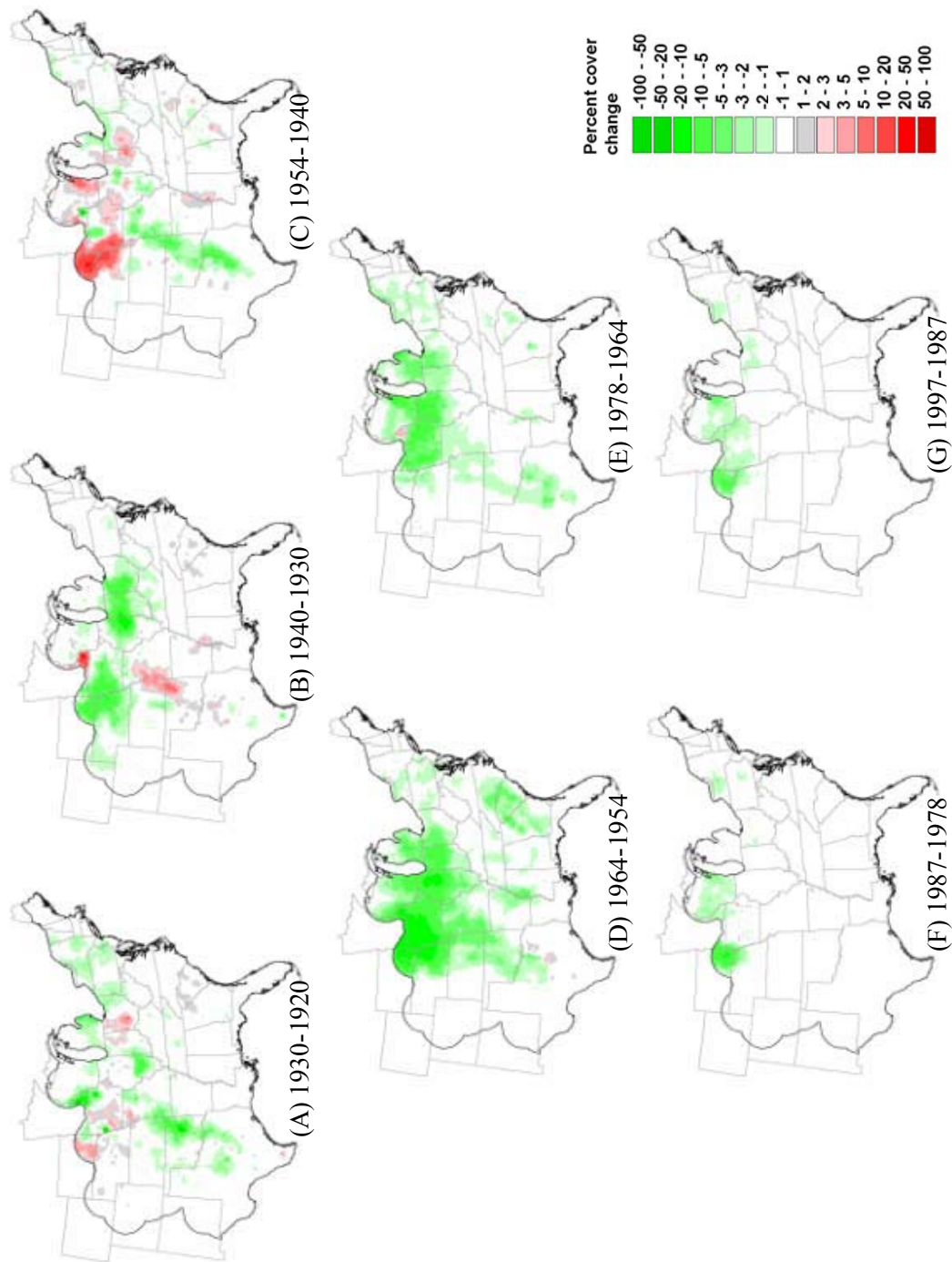


Fig. 3.45. Changes in oats cover in the northern bobwhite range, 1920-1997

Between 1964 and 1978, decline in oat cover persisted in the same places, with the exception of some areas in the southeast that had previously witnessed decreases, between 1954 and 1964. In addition, severe losses were observed during this period in Iowa, southern Wisconsin, and Michigan, northern Illinois and Ohio (Fig. 3.45E). Oat production was lost over much of South Dakota and Wisconsin from 1978 to 1997 (Fig. 3.45F-G).

Rice

The acreage of rice production remained relatively stable for more than 70 years (Fig. 3.46). There were no significant changes for this crop between 1920 and 1940 (Fig. 3.47A-B). However, the years following 1940 through 1954, rice cover experienced an increased production along the Mississippi River, and the Texas Coast and Louisiana (Fig. 3.47C).

The gains in rice cover that occurred in this area from 1940 to 1954, became losses between 1954 and 1964 (Fig. 3.47D). From 1964 to 1978, the trends in rice losses were reversed and an increase in the total rice production took place along the Mississippi River (Fig. 3.47E). Although no considerable changes happened in the decade of 1970s (Fig. 3.47F), rice production increased from 1987 to 1997 in southern Louisiana and eastern Arkansas (Fig. 3.47G).

Barley

Barley production over the NBW range declined dramatically over the seventy-year period and almost disappeared by the end of the 20th century (Fig. 3.48). Between

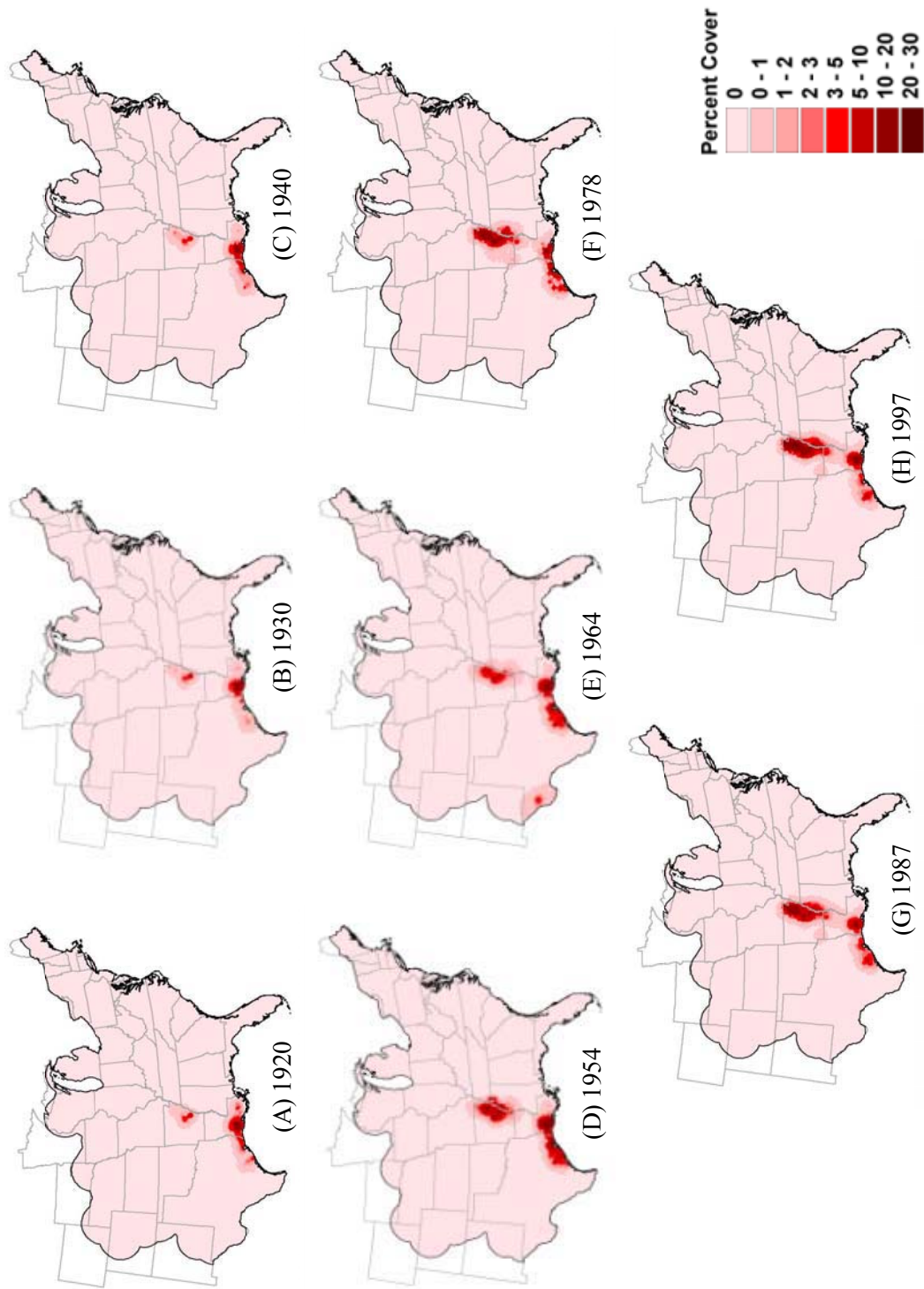


Fig. 3.46. Rice cover in the northern bobwhite range, 1920-1997

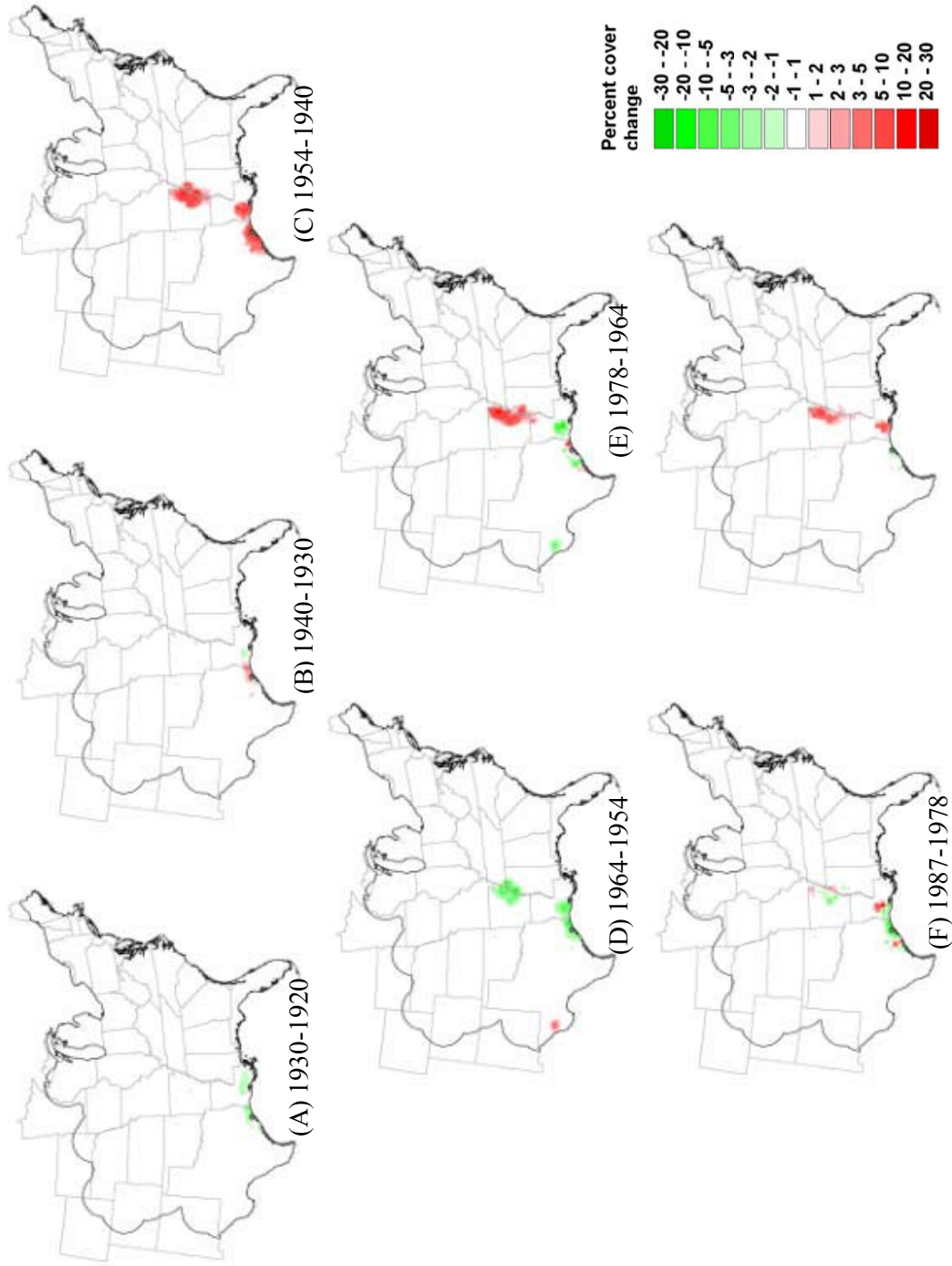


Fig. 3.47. Changes in rice cover in the northern bobwhite range, 1920-1997

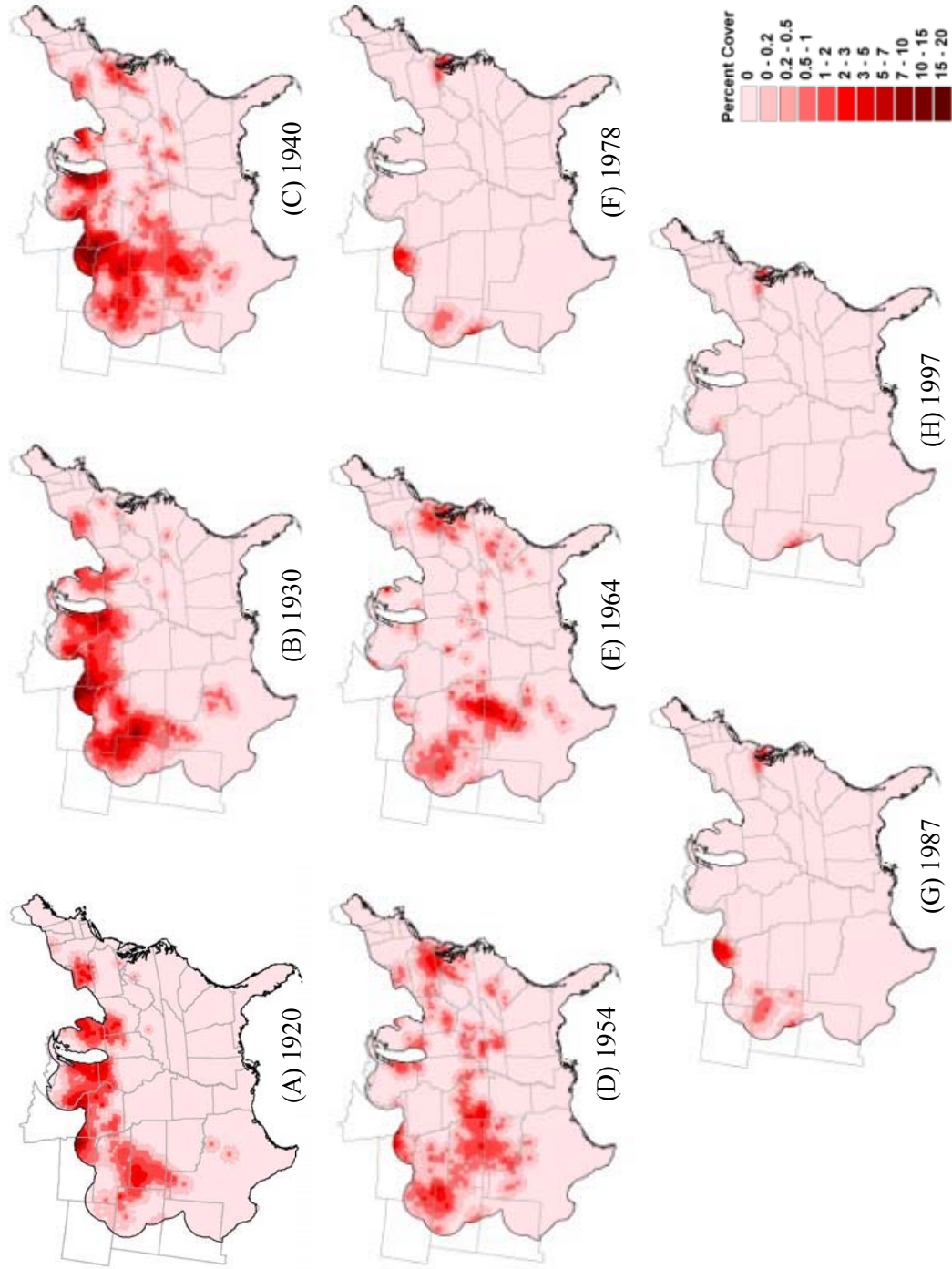


Fig. 3.48. Barley cover in the northern bobwhite range, 1920-1997

1920 and 1930 there was significant growth in the barley coverage observed in areas of Wyoming, Colorado, and western Nebraska, and Kansas. Other increases occurred during the same decade, mainly in South Dakota, northwestern Iowa and northern Illinois. Over the same period, some losses were observed in Kansas, Michigan and on the Indiana-Ohio border (Fig. 3.49A).

In the decade of the 1930s, most increases in barley coverage stretched from southern Oklahoma, through Kansas, into Nebraska, South Dakota and eastern Iowa. During this decade, barley production experienced significant decreases particularly in the area that include the states of Kansas, Nebraska, and Colorado. Another decline occurred in Iowa, Illinois and Wisconsin (Fig. 3.49B). Although the severest decline in barley acreage happened from 1940 through 1954, this took place in much of northern Kansas, southern and eastern Nebraska, South Dakota, western Iowa, southern Minnesota and eastern Wisconsin. During these years slight gains in barley cover occurred along the Missouri-Kansas border and in Pennsylvania (Fig. 3.49C).

Fragmented losses in barley cover were observed between 1954 and 1964, particularly in central portions of the NBW range. Only central Oklahoma experienced an increase in barley during this period (Fig. 3.49D). From 1964 through 1978, barley production declined considerably in eastern Oklahoma and southern Kansas. In the meantime, some parts of South Dakota witnessed minor gains in barley production (Fig. 3.49E). In the decade of 1970, there were almost no changes observed within the NBW range (Fig. 3.49F). However, between 1987 and 1997, barley cover decreased in South Dakota and northern Colorado (Fig. 3.49G).

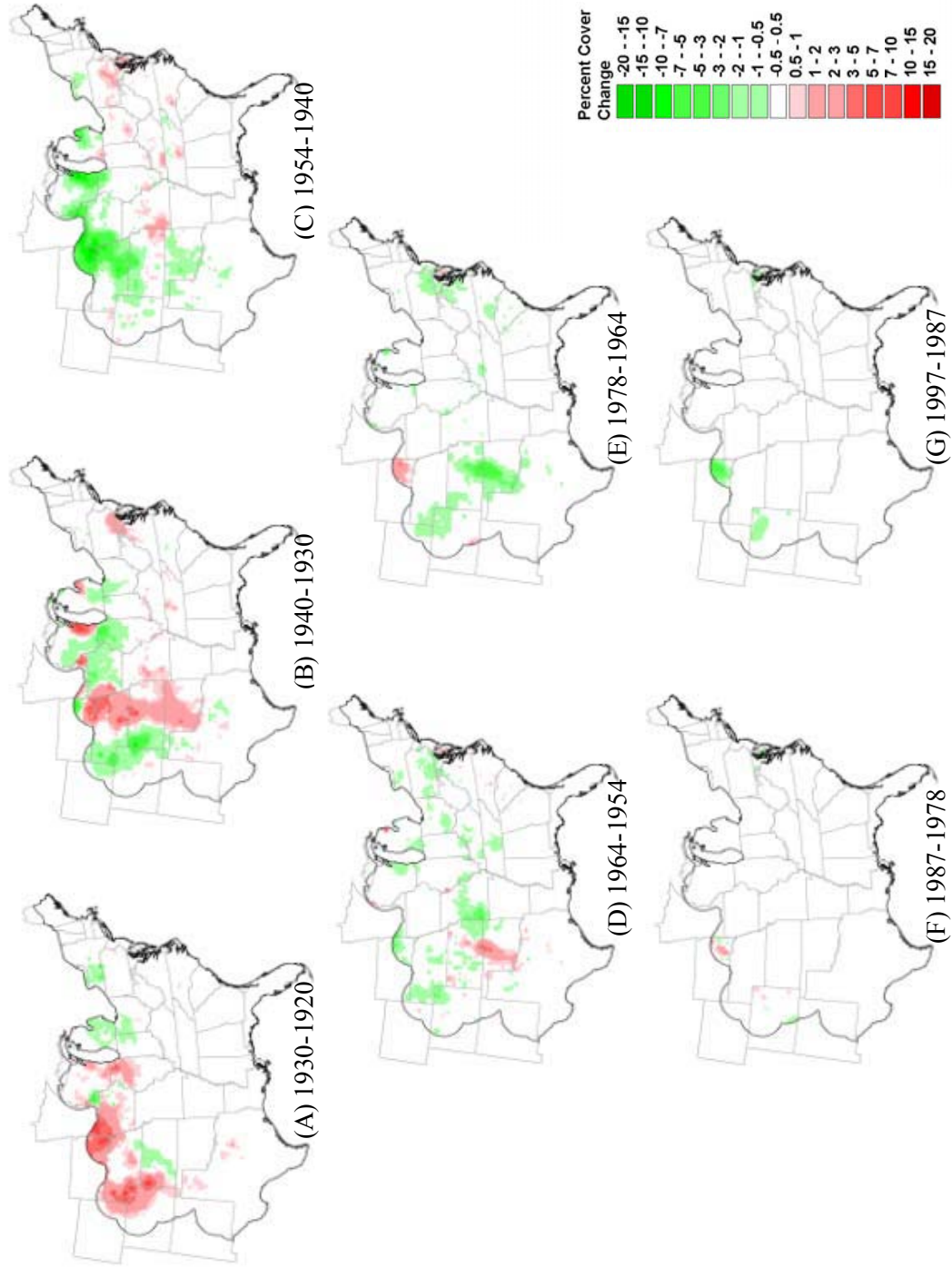


Fig. 3.49. Changes in barley cover in the northern bobwhite range, 1920-1997

Tobacco

Tobacco cover showed a relatively constant pattern since the 1920s, even though slight losses were observed in the middle of the century (Fig. 3.50). From 1920 to 1954, much of the decreases in tobacco production occurred in Tennessee and Virginia (Fig. 3.51A-C). In the decade of 1950s saw a dramatic decline in tobacco production in eastern North Carolina and Virginia (Fig. 3.51D). However, the same places that witnessed decreases in tobacco cover during the previous decade saw a significant increase from 1964 to 1978 (Fig. 3.51E). In the decade of 1970s, there were some losses of tobacco production in northern Virginia and southern Georgia (Fig. 3.51F). There were no changes in tobacco production between 1987 and 1997 (Fig. 3.51G).

Summary of Results

A general decline was noted in total cropland, total pastureland and harvested cropland over the NBW range, although significant fluctuations were observed in total woodland between 1920 and 1997. However, idle cropland fluctuated considerably during this period (Fig. 3.52). Over the 70-year period, some decreases were observed in corn, wheat, and hay production. In the meantime, sorghum, cotton, oats, barley and tobacco production declined severely, whereas enormous increases were observed in soybean and rice production from 1920 to 1997 (Fig. 3.53).

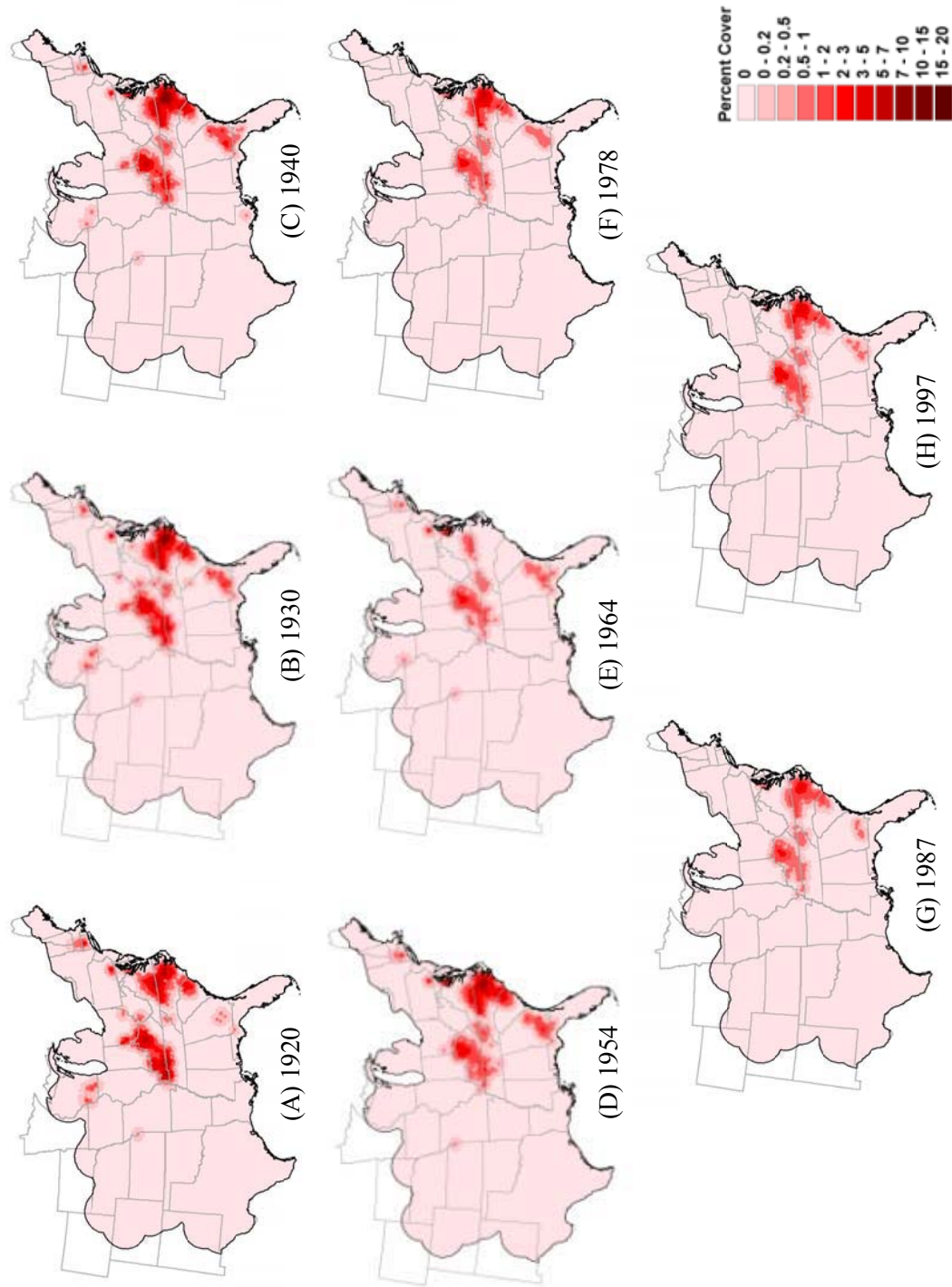


Fig. 3.50. Tobacco cover in the northern bobwhite range, 1920-1997

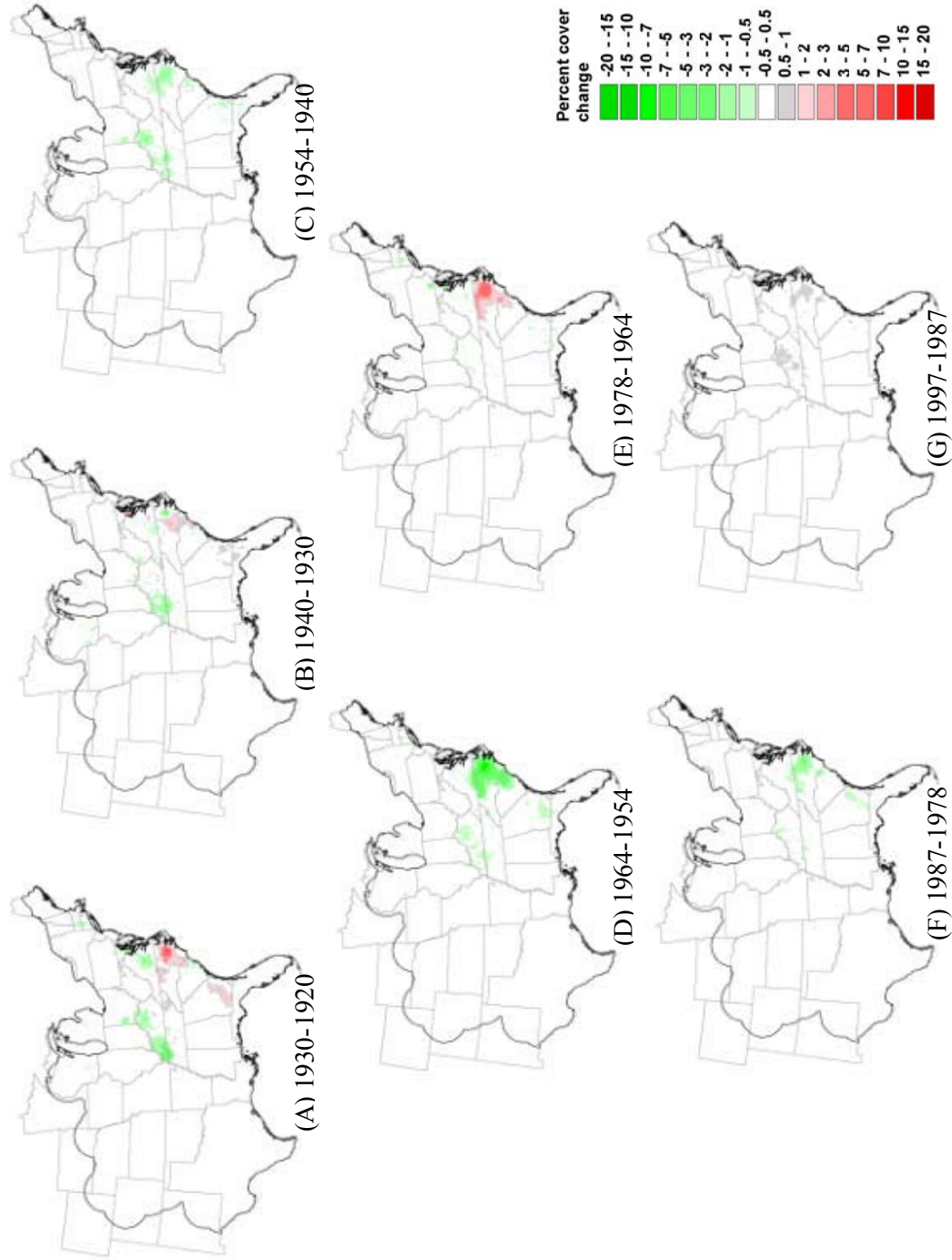


Fig. 3.51. Changes in tobacco cover in the northern bobwhite range, 1920-1997

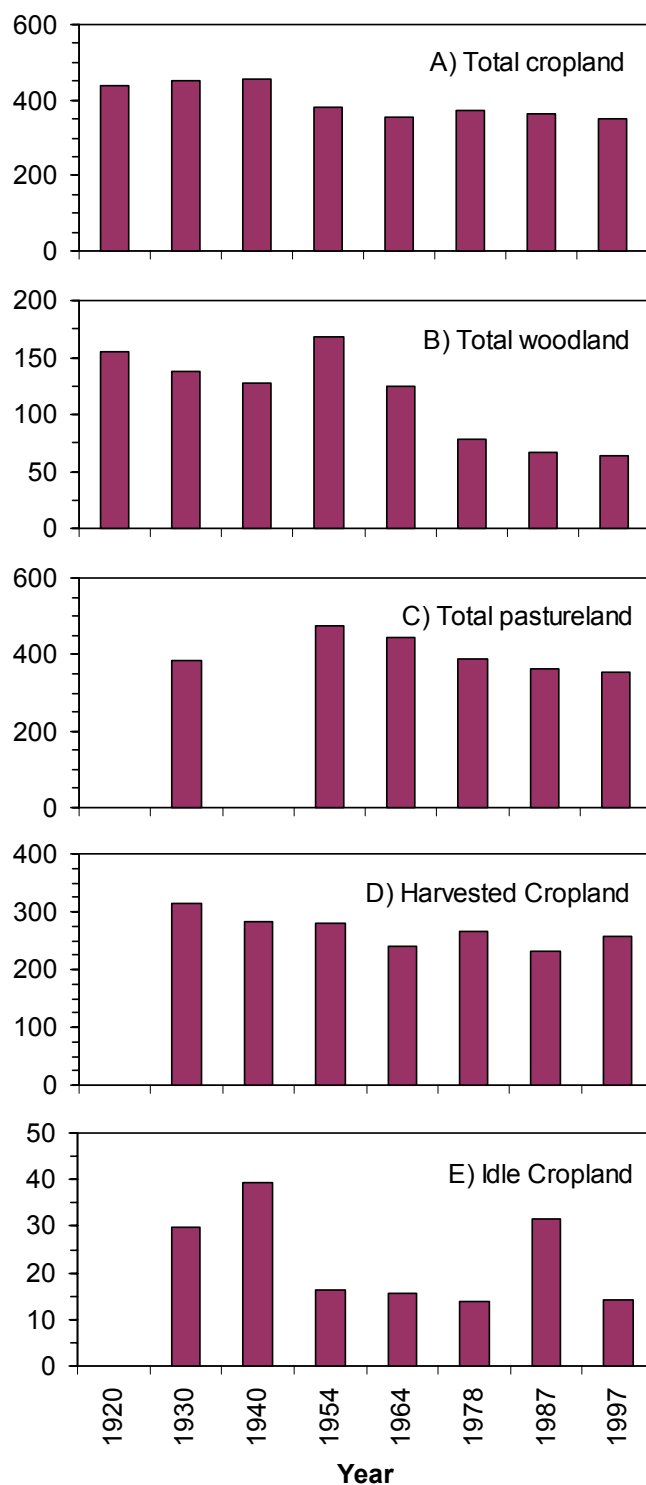


Fig. 3.52. Changes in acreages of land use types in the range of northern bobwhite based on the Census of Agriculture

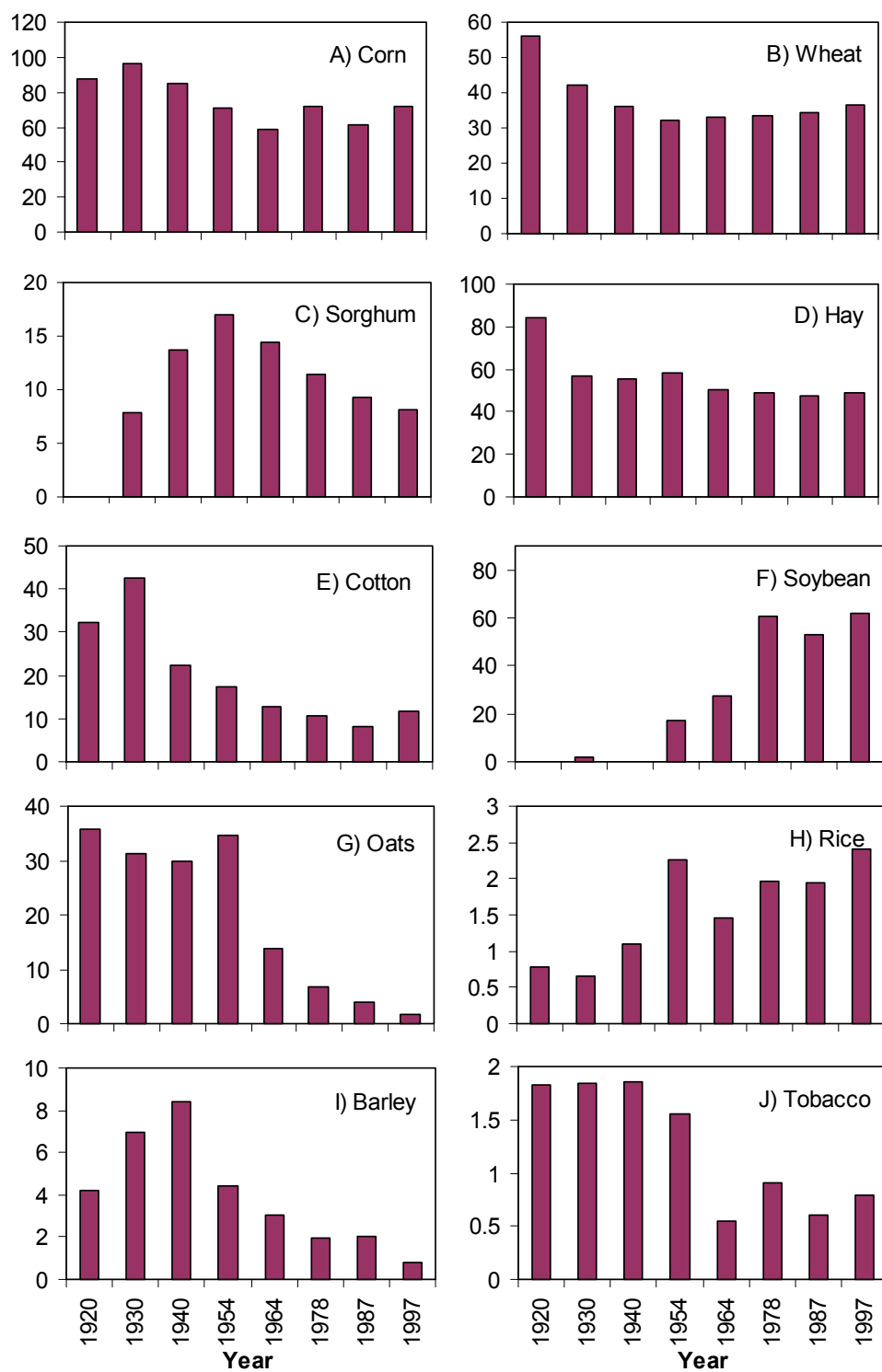


Fig. 3.53. Changes in acreages of crop types in the range of northern bobwhite based on the Census of Agriculture

DISCUSSION

The last three centuries have witnessed more human influence on nature than the preceding countless centuries of human existence on the Earth. Human beings have always been dependent on nature for obtaining food and erecting shelter to ensure their safety and survival. However, recently man has manipulated and drastically altered the state of nature on a wide range. This manipulation and modification of the Earth's biosphere and atmospheric composition resulted in damage to the environment and the ecosystem, as well as the swift depletion of natural resources and a decline in the number of other species with which we share the surface of the Earth and on which we depend for our survival (Ramankutty and Foley 1999).

The shifts in land cover (Baron et al. 1998) and the conversion of natural landscapes into agricultural and industrial sites and often into degraded land have had negative effects on the environment and ecosystem processes (Dobson et al. 1997). Particularly, vast and rapid modifications of land cover in the United States resulted in the loss of required habitat, not only for the threatened and endangered species, but also for other plant and animal species (Klopatek et al. 1979). In a similar way, land use changes in agriculture and forestry, which affect in millions of acres annually (Alig et al. 1998), tend to threaten biodiversity (Redford and Richter 1999), accelerate soil erosion (Burke et al. 1995), alter climate (Dale 1997, Baron et al. 1998, Bonan 2001) and reduce recreational opportunities, resulting in associated economic impacts (Alig et al. 1998).

In this sense, one must understand the dynamics, patterns and attributes of land use and land cover alterations over time in order to identify approaches for the improvement of natural resource management especially that involving animal species.

During the last centuries, the regions occupied by NBW, have experienced tremendous shifts in land use and land cover. These changes are largely the results of socio-economic changes in different periods and associated large-scale climate change (e.g., drought), the advent of new technologies, and government policies and programs.

Impact of European Colonization and Pioneer Agriculture

Agriculture became the preeminent feature of life as European settlers immigrated to the United States (Schlebecker 1975, Cochrane 1993, Sharitz et al. 1992). The first forests of America were rich in diversity and covered by dense hardwood and pine trees as far as an eye could reach (Lillard 1947). These early pioneers extensively cleared most of the pine and hardwood forest species particularly in the southern portions of the United States (Komarek 1974) to create new agricultural lands, pastures, towns, roads and for other uses (USDA Forest Service 1988). According to Clawson (1979) the forest clearing to form cropland and improved pasture was not very severe until the 1800s when compared with the rapid land clearings of the following years. Significant decline in forestland started at the beginning of 19th century and continued throughout the 1920s.

As new settlers continued to expand and harvest forestland, cultivated areas continued to increase, reaching a peak around the 1920s and in early 1930s (Fig. 3.1), leaving behind small isolated remnants of the remaining southern forests surrounded by a vast area of agricultural land (Sharitz et al. 1992). Between 1880 and 1930, over 350 million acres of forestland was lost across the Nation (Clawson 1979). Particularly, the extensive forests of the Georgia Piedmont region were modified for new farm practices around the 1800's (Brender 1952, 1974, Cowell 1998) and nearly four-fifths of the

forestland had already disappeared and been intensively cultivated by the 1930s (Turner and Ruscher 1988). According to Pinder III et al. (1999) by the 1920s over 20 million hectare of pre-Columbian forestland had been reduced to about 1 million hectare in South Carolina and Georgia alone.

Before the period of frontier settlement, the number of NBW in the natural forests was limited (Bolgiano 2000). As the forests were cleared and fields cultivated for agriculture and livestock grazing, it is believed that habitat for NBW were created and as a result, NBW abundance increased dramatically (Leopold 1931, Edminster 1954, Kozicky 1993). Rosene (1969) conjectured that this increase in NBW abundance continued in the North until 1860s and in the South until 1890s and remained relatively stable for a few decades in most parts of the range. However, this trend was reversed by the 1940s and NBW abundance began to decline in response to intensified farm practices (Bolgiano 2000) (Fig. 2.1C).

Impact of the Golden Age

The years between 1898 and 1914 in American history have been called the ‘Golden Age’ since many farmers experienced significant economic growth and affluence because of boosts in agricultural production (Cochrane 1993, Hurt 2002). During that period, low farm and high agricultural prices enabled most farmers to purchase new equipments and learn new techniques (White 1991, Hurt 1994). In particular, the development of the gasoline-engine tractor at the beginning of the 20th century reduced the importance of animal power used for centuries for soil plowing (Schlebecker 1975, Gardner 2002). Afterward, the use of tractor in the agricultural

production increased dramatically. For example, the number of tractors in the production rose from 4000 to 246,000 between 1911 and 1920. This number tripled a decade later and came up to 920,000 in 1930 (Cochrane 1993). As farm equipment became larger, the size of the farm continued to increase (Batie and Healy 1980).

These improvements in mechanization and production reduced the need to have pastures and meadows (Edwards 1994). At that time, the acreage of hay and oat production was more widespread than they are now. These hay and oat farms, previously used for animal feed, were replaced with other crops (Batie and Healy 1980). In addition, farmers extended new agricultural products to the other regions. For instance, cotton was introduced to Oklahoma and western Texas. Most forests in Kansas, Nebraska and the Dakotas were harvested for produce more wheat (Schlebecker 1973).

Most farmers enjoyed prosperity during the American golden age, as a result of improvements in technology and productivity. However, the concurrent reduction in the acreage of woodlands, pasturelands, and certain crop species due to intensive mechanization corresponded with large-scale habitat losses for many wildlife species, including NBW (Edwards 1994).

Impact of World War I

With the beginning of World War I, agriculture in Europe was disrupted severely and American farmers were encouraged by the Food Administration to produce more food and fiber with the slogan of “Food will win the war” (Edwards 1985, Drache 1996, Hurt 2002). In a response to meet the demand, farmers planted cash crops, particularly wheat, cotton and tobacco on the lands that were used previously as timberland or

grassland. Many self-sufficient small farmers also began to plant cash crops to meet the new markets demand (Alston 1983).

Between 1913 and 1919, the acreage of wheat production increased 42 percent (Drache 1996) and cotton production reached its highest level with 37 million acres in 1918 (Hibbard 1960). According to Fite (1948), many pastureland areas, previously used for cattle range, were converted to cotton production. As a result, the acreage of cotton was expanded tremendously, particularly in Texas and Oklahoma. Many farms, formerly devoted to cereal grain production, were also reserved for cash crops production that brought about dramatic decline in cereal grains (Hurt 1994).

According to Moss (1939), the reduction in the acreage of cereal grains in Connecticut resulted in decrease in NBW abundance. Similarly, Edwards (1972) attributed diminished NBW abundance in Illinois to a decline in cereal grains, particularly oats. Vance (1976) suggested that the conversion of grasslands to cash crop production corresponded with a reduction in the number of NBW in southeastern Illinois.

American farmers even intensively cultivated marginal farmlands in addition to the areas that were suitable for best farming practices (Healy 1985, Hurt 1994). These areas, mostly used for wheat production in the Great Plains and cotton production in the South, exhausted the topsoil resulting in soil erosion (Maher 2000) and nutrient leaching (Bowden 1977). Planting one type of crop species in the same place in a long period of time without rotation reduces soil fertility and productivity. Stoddard (1931) stated that the decrease in soil fertility due to explosive agriculture practices contributed to the depletion of the food supply for NBW that reduced the number of these species.

During the wartime, the rate of adoption of technology and mechanization was also accelerated so as to lessen the impact of labor shortages on the farms (Hurt 1994). According to Duck and Fletcher (1943), the intensive use of machine in the fields during and after the World War I caused a severe reduction in NBW habitat that gave rise to decline in this specie in western Oklahoma.

Although World War I was considered as a turning point in American agriculture, since most farmers took advantages of the opportunities presented to export their surpluses to the international market as well as to acquire new machines to increase their productions (Batie and Healy 1980, Drache 1996). There are strong believes that intensive monoculture practices across the Nation associated with mechanization diminished the habitat that the NBW needed (Duck and Fletcher 1943, Vance 1976, Exum et al. 1982, Burger 2002).

Changes in the Post-World War I Era

The prosperity which American farmers experienced did not last long due to the curtailed demand for farm products at the conclusion of World War I. However, farmers continued to cultivate more acreage in the hope of producing enough grain to feed their and livestock to reimburse their equipment and land (Hurt 1994). During that period, considerable increases were observed in the cropland areas by drainage, clearing, irrigating and plowing up grasslands (Fig. 4.48A) (Reuss et al. 1948). Most of the states in the South, particularly Florida, Arkansas, Louisiana experienced a significant amount of increase in the cropland acreage in the 1930s (Figs. 3.1B, 3.2B). Widespread corn

(Fig. 3.53A) and cotton (Fig. 3.53E) production across the Nation continued during the 1920s and 1930s (Haystead and Fite 1955).

Overproduction in agriculture started to become a serious problem that resulted in a sharp fall in crop prices (Hurt 1994). Since many farmers had difficulty in paying the mortgages of their farms, thousands of them all over the United States could not withstand and were faced with bankruptcies by the 1930s (Fite 1962, Cochrane 1993). Therefore, many of the landowners and tenant farmers withdrew from production and abandoned their lands (Fig. 3.52E) (Bowden 1977).

During this period, significant increase was observed in NBW abundance as these “worn out” abandoned farms provided suitable habitats for one or two years after the abandonment. However, within a few years this trend was reversed, and species’ abundance declined tremendously since these abandoned farms were covered with species such as broomsedge grasses and other grasses that increased plant cover and litter which reduced the volume of these areas for NBW (Stoddard 1931, Goodrum 1949, Rosene 1969, Roseberry et al. 1979). Such areas in the following decades were replanted with pine trees, which provided unfavorable conditions for NBW species (Goodrum 1949).

Edwards (1994) speculated that there had been an inverse relationship between trends in wildlife abundance and the prices of agricultural products. The high cost of equipment and low agricultural prices always compelled farmers to use land intensively, which led to the decline of many upland game species, including the NBW. Since the demand for farm products diminished during the economic depression of the 1930s, intensive land use practices lessened (Cochrane 1993). Thus, a significant increase in

NBW habitat was experienced with a concurrent rise in their abundance during that period (Edwards 1994).

The sudden fall in the market for farm products the end of World War I, gave rise to farm bankruptcies across the United States and many farmers abandoned their farms accordingly. Land abandonment might create a favorable habitat that NBW requires for a short time. However, these species begin to decline as early successional habitat has been replaced by secondary succession.

Impact of Dust Bowl

The agricultural economic situation became worse after the stock market crash of 1929 that marked the beginning of the Great Depression (Hurt 1994). In the meantime, severe drought and poor land management practices created a series of wind and dust storms, known as the 'Dust Bowl', which affected most parts of the central and southern Great Plains at the beginning of 1930s (Warrick et al. 1975, Hurt 1981, White 1991). The Dust Bowl lasted for almost a decade and took place mostly in Kansas, northeastern New Mexico, southeastern Colorado and the panhandles of Oklahoma and Texas (Warrick et al. 1975, Cunfer 2001).

Before the settlers arrived on the Great Plains, the region was originally covered with grasses (Forsythe 1977, Lauenroth et al. 1999). During the early 1900's, a number of farmers settled into the region and converted the natural grasslands to wheat and row crop productions, which did not have the enough capacity to hold the fine soil in place (Worster 1979, Wunder et al. 1999, Cunfer 2001). Moreover, the rest of the grassland areas in the region were devastated by overgrazing (Fulton 1977, Hurt 1981). As a result,

the soil was blown away when the drought and strong winds hit the lands. The effects of the drought were very severe, literally tons of soil was blown off the land, crop fields were destroyed, equipment and machinery was ruined, livestock was killed, and human lives were harmed (Schlebecker 1973, Warrick et al. 1975, Dolan 1990, Wunder et al. 1999).

The agricultural and economic depression across the Nation in combination with the Dust Bowl in the Great Plains resulted in abandonment of thousands of hectares of agricultural and marginal lands in addition to the failed field during the dust storms years (Figs. 3.11, 3.12A) (Goodrum 1949, Warrick 1980, Alig et al. 2003). According to Duck and Fletcher (1943), western Oklahoma experienced a significant growth in NBW abundance for a limited time as farms were abandoned in that region around the 1930s due to Dust Bowl.

Despite intensive drought, there was an observed increase in NBW abundance in some parts of the Great Plains for a short time due to the abandonment of farms during the Dust Bowl.

Impact of Federal Programs of the 1930s

The Great Depression, associated with the Dust Bowl in the Great Plains made life tremendously worse for American farmers even though some federal agricultural aid programs provided economic relief to them (Alston 1983, Maher 2000). The first Federal action was taken in May 1933 through the ‘Agricultural Adjustment Act (AAA)’ as a part of Franklin D. Roosevelt’s New Deal program to raise and stabilize farm prices and income (Alston 1983). The AAA gave benefit payments to farmers for reducing the

amount of staple crops, which they marketed (Perkins 1980) and taking marginal lands out of production (Fite 1962, Cochrane 1993, Cunfer 2001). Particularly, the cotton acreage in the South declined dramatically (Figs. 3.41B, 3.53E) during this period due to the limited production under Agricultural Adjustment Act, severe boll weevil infestation, labor shortages caused by mechanization and outmigration and drastic erosion problems resulting from soil exhaustion (Healy 1985).

In general, a reduction occurred in harvested cropland area between 1930 and 1940 (Figs. 3.5, 3.6A, 3.52D). Conversely, the acreage of idle and fallow land ascended (Figs. 3.13, 3.14A, 3.52E) and the rate of farm abandonment rose during that decade (Ward 1946). Meanwhile, the acreages of corn (Fig. 3.53A), cotton (Fig. 3.53E) and wheat (Fig. 3.53B) production declined while hay (Fig. 3.53D), soybean and other crops increased (Reuss et al. 1948). The acreage of cotton production in the South was about 23 million in the 1920s whereas this rate dropped to only 2.9 million in the 1982. In the same way, corn acreage in the South fell from 24 million to 19 million between 1929 and 1949. In the early 1980s only 7.4 million acres remained in corn production (Healy 1985). Much of the acreage devoted for wheat production in the Great Plains during the depression was replaced with sorghum production at the end of the 1940s (Fig. 3.53C) (Haystead and Fite 1955).

The AAA also attempted to encouraged farmers to practice crop diversification and planting of soil-building crops on their lands (Nourse et al. 1937, McJimsey 2000) since most of the farmers, particularly in the South, had disregarded diversified farming and crop rotation practices for decades and concentrated mostly on monoculture production, mainly cash crops (Stoddard 1931, Hart 1978, Batie and Healy 1980). In

addition, the Soil Conservation and Domestic Allotment Act of 1936 was supplemented by a new Agricultural Adjustment Act of 1938 to help farmers carry out some soil conservation practices and erosion control projects (Schlebecker 1975, Hurt 1994). Although these programs assisted farmers to recover and offered a variety of agricultural practices, they could not improve NBW habitat (Rosene 1969). With the beginning of World War II, the AAA lost its meaning since there was an increasing demand for farm products to meet war needs (Cochrane 1993).

The federal programs were designed to rehabilitate farmers by reducing production of staple crops, to raise farm prices, and to encourage more diversified farm practices. Farmers were given benefit payments in return for decreasing their production and encouraging conservation practices by planting soil-building crops instead of staple crops. As discussed previously, the increase in the idle and fallow fields in a long-term period might have caused a serious decline in NBW abundance during that period.

Impact of World War II

Federal programs assisted farmers in a manner of ways: through loan assistance, the initiation of soil conservation programs, and the development of infrastructure through the Tennessee Valley Authority to enable electricity to reach farms. However, low agricultural prices, over production and over population in agricultural areas remained as major problems of during the 1930s (Hurt 2002).

This situation was reversed as the United States entered World War II. Agricultural surpluses were rapidly diminished when the demand for food and fiber increased to support the military and industrial workers. This caused farm prices and

incomes to rise (Cochrane 1993). During the war years, an exceptional boost was experienced in agricultural production. There was a great expansion in the acreage of harvested cropland and a contraction in the acreage of idle and fallow land (Fig. 3.52E). Moreover, numerous pastureland and rangeland areas were converted into crop production at the same time (Reuss et al. 1948).

This increase in production also continued into the early postwar years (Johnson 1960). Soybeans production exploded after World War II (Figs. 3.42, 3.43B) although this crop was hardly known during the 1920s (Fig. 3.53F) (Hart 1986). Soybeans became a favorite crop among the farmers since their production and harvest could be easily done through mechanization. Additionally, like cotton, soybeans always had a market, and tenants could not consume it directly (Haystead and Fite 1955). As a result, many of the corn farms in the Corn Belt (Hart 1978, Raup 1980) and cotton farms in the South (Hart 1978, Healy 1985) were replaced with soybeans. The acreage devoted to soybean production increased from 14 million to 63 million between 1950 and 1978 (Batie and Healy 1980). Unlike soybean, corn acreage (Figs. 3.32, 3.33C, 3.53A) declined about 30 million acres from 1932 to the late 1950s (Alig et al. 2003).

Stoddard (1931) believed that in order to produce more soybeans, tenant farmers increased the amount of herbicides and insecticides that caused a severe reduction in the number of NBW. Soybean forms a major portion of the NBW's diet in the fall, winter and spring. However, it provides very poor nesting and brood habitat for these species (Stoddard 1931, Lee and Brennan 1994). The total acreage of rice production also expanded extensively at this time to include many fertile fields particularly in Louisiana,

Arkansas and Texas (Figs. 3.46, 3.47C, 3.53H) (Haystead and Fite 1955, Healy 1985). According to Hart (1978) the areas used in rice production almost tripled by 1974.

A sufficient food supply is essential for NBW population to survive and flourish. However, the quality and quantity of ground cover also play a critical role in NBW production. Rosene (1969) assumed that the deficiencies in the quality and quantity of cover in the southeastern states, from 1940 to 1955, caused a severe reduction in NBW abundance. Similarly, Baerg and Warren (1949) inferred that a significant decline in NBW abundance in Arkansas, between 1942 and 1946, was due to unfavorable habitat conditions. Their nest cover was deteriorated by wet ground although rice and soybean production in that region were abundant. Dimmick (1992) also stated that the reduction in NBW abundance at Ames Plantation in western Tennessee, from 1966 to 1991, was the consequence of nesting habitat loss.

The war created new job opportunities, and employment rates across the Nation rose accordingly (Schlebecker 1973, Cochrane 1993). However, farm population began to drop severely. With the beginning of World War II, the migration process was intensified and a number of farm workers, particularly white farmers, left their lands and moved to the cities. However, the Great Depression of the 1930s forced many of them to return their farms (Cochrane 1993). Farm population decreased from 30 million in the 1940s to 23 million by the 1950s (Schlebecker 1975). The South experienced the highest emigration rates in the United States (Reuss et al 1948, Hurt 1994). There was a 20.4 % decline in farm population in the South, from 1940 to 1945; where as, this rate was about 0.20 % from 1930 to 1950 in the North (Hurt 1994).

In the meantime, farm sizes and productivity continued to increase despite a decreasing number of farm number and population (Figs. 3.28, 3.29, 3.30, 3.31) (Goodrum 1949, Brennan 1991, Drache 1996, Gardner 2002). The replacement of man and animal power by mechanization was one of the most influential factors leading to increase of farm sizes and farm productivity (Johnson 1960, Cochrane 1958). According to Stewart et al. (2004), size of farms in Mississippi increased from 22 to 337 hectares between 1942 and 1992. On the other hand, the number of farms decreased from 291,092 in 1942 to 42,415 in 1982 (Brennan 1991).

Technological revolutions occurred during the war and in the early postwar years, which allowed many farmers to possess extensive mechanization, use improved crop varieties, and consume more chemical fertilizers in their lands for the efficient control of insects, and diseases (Johnson 1960). These revolutions were adopted at once because of labor shortages on the farms and improved financial enhancement of farmers due to rising farm prices (Cochrane 1993). Between 1920 and 1945, more than 2 million tractors were used for production (Johnson 1960). Large amount of chemical fertilizers were applied to fields to double and even triple farm productivity and yields. Pesticides were used for insects and disease control; while herbicides were applied for weed control also (Hart 1986).

The application of pesticides to farm fields limited the abundance of arthropods, which are a good source of protein, particularly for growing chicks (Brennan 1994, 1999). Meanwhile the use of herbicides eliminated weedy plants needed by NBW as food and cover. In addition, the practice of crop rotation, to sustain soil fertility was disregarded due to low-priced, nitrogen fertilizers and pesticides, which resulted in less

perennial cover and the loss of habitat for most game species (Edwards 1994). Intensive mechanization caused a serious reduction in the number of NBW by removing their food supply after harvesting (Stoddard 1931). In particular, mechanical pickers replaced handpicking (Hart 1986) and thus captured a greater percentage of the crops and grain yields, leaving little residual feed on the ground for these species to eat (Rosene 1969).

Mechanization also eliminated millions of acres of small fields, woody thickets on ditch banks, idle corners, weedy patches, fencerows grown into brush, and shrubby borders of woodlots that had previously provided feeding, nesting and protective cover for NBW. (Leopold 1931, Stoddard 1931, Goodrum 1949, Rosene 1969). Kabat and Thompson (1963) speculated that the removal of hedgerows brought about a reduction in the abundance of NBW.

Many sharecropper and tenant farmers had already been dismissed from the farm production during the New Deal programs of the 1930s (Whatley 1983) when the AAA remunerated landowner to reduce mostly cotton production, which resulted in farmers to use this money to buy tractor and other equipment. As a result, landowners “combined small farms into large fields, removed houses and fences, and used tractors, cultivators, and mechanical planters to plow, seed, and weed the cotton crop” to facilitate harvesting (Hurt 2002). The slogan “Get Bigger or Go Under” also encouraged the farmers in the Corn Belt Region to increase the size of their farms. The average size of the farms in this region almost doubled from 1949 to 1982 with the new technology, which resulted in considerable increases in corn acreage (Hart 1986).

The usage of high-yielding crop varieties, mechanization, fertilization and pesticides in the fields brought about more expansion and intensification in cultivation,

which (Klimstra 1982, Roseberry and Sudkamp 1998) lessened livestock species as well as many wildlife species (Matson et al. 1997). As intensive agriculture augmented, farmers continued to enlarge their farm sizes. Increasing farm sizes generally eliminated brushy and weedy plants that served as a nesting habitat and protecting cover for NBW species (Exum et al. 1982, Roseberry and Klimstra 1984). According to Roseberry et al (1979), there was more than an 80 percent decline in the abundance of NBW over a nine-year period in southern Illinois as a result of the deteriorating habitat associated with intensive agricultural practices.

With the beginning of World War II, mechanization and clean farming practices were accelerated dramatically in response to the demand for agricultural productions and because of labor shortages. Small farms with diverse cropping pattern were united into larger farms that eliminated networks of hedgerows and brushy fencerows necessary for NBW. These larger farms reduced landscape heterogeneity that was characterized by a high degree of connectivity and a habitat quality for NBW.

Changes in the Post-World War II Era and the Following Years

American agriculture changed rapidly after World War II. Improvements in technology and science allowed farmers to become more productive and efficient than ever before. During the hard times of the 1930s and for a period after World War II much cropland and pastureland in the South had been left idle and allowed to lay fallow. Much of these areas regenerated naturally or were planted to forest by the Civilian Conservation Corps in the 1930s and by the Soil Bank Program in the early 1960s (Plair

and Spillers 1960, Hart 1968, Healy 1985, Williams 1989) resulting in a significant increase in the forestland from 1930s to 1954s (Figs. 3.15, 3.16B-C).

In addition, the abandoned cotton lands in the South, cleared-out forestlands in the East and marginal lands in the other regions were converted to forests from 1930s till the early 1960s (Alig et al. 2003). The forest area across the United States increased by 762 million acres between 1952 and 1963, which reached a postwar peak (Alig et al. 2003). During these years, the enormous conversion to forestland across the United States occurred in the South, where 60 percent of the total land in the region was classified as timberland (USDA Forest Service 1988).

Agricultural areas were reverted back to forest between 1939 and 1974, particularly in the Piedmont region, which was the main cotton producing area in the South (Hart 1980, Turner and Ruscher 1988, Williams 1989). According to Odum (1989) Georgia lost approximately 50 percent of the croplands since the 1940s (Figs. 3.5, 3.6B-C). Conversely, forestlands in the state increased (Fig. 3.16B-C) to about 65 percent. During this period, the abundance of NBW showed a downward trend in most parts of their range (Speake 1966). These areas converted to pine plantations provide good habitat quality for NBW species during the initial 2 to 7 years. However, as pine plantations became highly dense, their closed canopies diminished sunlight on the forest floor and eliminated the understory habitat for NBW (Speake 1966, Landers and Mueller 1986, Stauffer et al. 1990, Brennan 1991, Stewart et al. 2004).

There was an immense shift in the North from cropland to pastureland and hay production before and shortly after the World War II due to the demand for dairy products (Hurt 1994). Moreover, most of the corn and oat farms in New York, New

Jersey and Pennsylvania were used as substitute for hay during this period (Haystead and Fite 1955). Following the war, some of the pastureland and other agricultural areas were abundant and then converted to forest area due to the reduction in dairy farm production (Alig et al. 2003). The rest of these pastureland areas were contracted by the Soil Conservation Program to produce perennial legumes and grasses in the mid 1950s. However, they were later reverted back to cropland as their contracts expired in the 1960s. The grasses and legumes promoted under the Soil Conservation Program were very efficient in soil erosion control and wildlife habitat cover; however, their disappearance was correlated with a significant decline in NBW abundance in most of the Midwest (Edwards 1994).

This increasing trend was reversed by the 1960s and acreage for timberland production started to decline (Figs. 3.15, 3.16D, 3.52B). From 1962 through 1997, 492 million acres of timberland were lost (Alig et al. 2003). During the 1960s numerous cropland areas were augmented (Fig. 3.2E) as a result of forest clearing. Particularly, the bottomland forests of the Mississippi Delta were cleared for soybean production (Figs. 3.15, 3.16E). Similarly, Atlantic coastline of North Carolina was cleared and put into crop production during the 1970s (Figs. 3.15, 3.16E). The following years, the forest clearing extended all the way through the Coastal Plain (Figs. 3.15, 3.16E-F). The forests of the upland region were also razed for pastureland (Healy 1985). Over the past several decades, most of the lands in agriculture and forestry were cleared for urbanization and infrastructural development (Vesterby et al. 1994).

In addition, during the 1970s irrigation increased, particularly in the lower Coastal Plains, and Delta region including Florida, Arkansas, and Louisiana resulting in

expansion in the acreage of rice (Figs. 3.46, 3.47E), cotton and soybeans (Figs. 3.42, 3.43D) (Healy 1985). Severe droughts that occurred in the 1970s and 1980s diminished crop production all over the world, but that enhanced the cropland production in the United States between 1972 and 1981 (Fig. 3.52D). During these years, wheat acreage increased to 34 million, corn acreage increased 20 million, cotton acreage increased to 3 million and soybean acreage increased to 28 million (Alig et al. 1998). However, in the late 1980s, an overproduction in agriculture was observed all over the United States due to reduced crop exports. As a result, the total cropland area declined (Figs. 3.2, 3.2F, 3.52A) and million of acres of cropland were left idle (Figs. 3.13, 3.14E, 3.52E) by Federal government programs (Alig et al. 2003). Even though minor increases were experienced in cropland harvested area, significant decreases were observed in cropland pastured (Figs. 3.7, 3.8E) and other cropland areas (Daugherty 1995). Particularly, the acreages of barley (Figs. 3.48, 3.49F) and oat (Figs. 3.44, 3.45F, 3.53G) were reduced tremendously since either more profitable crops replaced them or the fields were held idle (USDA 1998). The downward trend has become worse and these two grains have begun to be imported from other countries in recent years

The years following the war, much of the abandoned croplands and pasturelands were planted with pines and reverted back to forest. The abundance of NBW showed a downward trend accordingly as the pine forests created very poor habitat quality for them as their canopies closed. In the 1960s forests were cleared again and used for crop production or livestock grazing. This increasing trend in cropland and pastureland was reversed and in the late 1980's these areas were held idle because of overproduction.

Impact of Conservation Reserve Program (CRP)

In 1985 Congress replaced the 1981 farm legislation with the Food Security Act. The act provided for a long-term retirement program similar to the Soil Bank Program but now called the Conservation Reserve Program (CRP), in which the government paid farmers for taking the land out of production and returning it to the grassland and forestland and other soil protection uses for a 10-year contracted period (Cochrane 1993, Drache 1996, Klute et al. 1997). Although the CRP was initiated in 1985, there was a significant increase noted in the acreage of CRP cover within a decade (Fig. 3.27). For instance, in Mississippi under the CRP, more than 60 percent of land was converted to pine forests and hundreds of thousands of acres were transformed to permanent grass cover (Stewart 2004).

Even though many government incentives like CRP attempted to enhance wildlife habitat for decades, it is believed that they had negative effect on NBW abundance (Brennan 2002). CRP diminished NBW by planting more fescue pastures (Brennan 2002) and converting a number of croplands to loblolly pine (Dimmick et al. 2002). The farms under the CRP contract have different types of grasses, annual weeds and bare ground during the first 3 years. However, when the lands began to age, the abundance of grasses accumulates and annual weeds and bare ground diminish (Stewart 2004). Since the habitat quality was deteriorated, the number of NBW declined dramatically (Stewart 2004).

Although CRP facilitated well-dispersed and high quality grassland habitat for many wildlife species by retiring highly erodible and environmentally sensitive areas over a long-term period, this program provided limited opportunities for NBW.

CONCLUSIONS

In the past century over the range of NBW, land use pattern related to agriculture were highly dynamic and had undergone tremendous changes. Federal agricultural policies, as well as associated major socio-economic events and natural disasters, were the major drivers of these land use changes. NBW and many other wildlife species have been very likely affected by the changing patterns of agricultural land use. Insights into historical changes in agricultural land use and the influence of policy and other drivers on these alterations can help develop a better understanding of reasons for the dramatic decline of NBW across its range.

As European settlers immigrated to the United States, they cleared the dense pine and hardwood forests to cultivate it for agriculture and livestock grazing. With the continued expansion of settlement and harvest of forestland, the area of cropland continued to increase and reached a peak around the 1920s and early 1930s. The upward trend in the acreage of cropland was accelerated, particularly during the golden age of American due to the improvements in technology and mechanization. The demand for intensive mechanization reduced pasturelands; particularly the acreages, previously devoted to hay and oats production were replaced with other crops.

With the beginning of World War I, American farmers were encouraged by the government to produce more food and fiber. As a result, cash crops production, particularly wheat, corn, cotton and tobacco production was intensified across the United States. However, significant reduction was experienced in the acreage of cereal grains simultaneously. In addition, marginal farmlands were placed into production that caused

severe erosion and nutrient leaching in the soil. Mechanization and industrialization became fundamental parts of the farming practices during this period.

At the end of World War I, however, farmers continued to produce cash crops for a short time to compensate their farms and equipment that resulted in significant increases in the cropland areas, particularly most parts of the southern states. As the demand for farm products decreased afterward, many farmers could not afford to pay their mortgages of their farm and farm equipment, which brought about farm abandonment. The collapse in agriculture and economy associated with the Dust Bowl in the Great Plains enhanced farm abandonment all over the United States.

Some federal aid programs such as the Agricultural Adjustment Act and the Soil Conservation and Domestic Act were established to provide compensation to farmers who adjust the acreage of their soil-depleting crops and take marginal lands from production. The acreage of cotton, corn and wheat production decreased accordingly. But, the production of soybean, hay and sorghum were increased tremendously.

In the meantime, significant declines were noted in the acreage of harvested cropland. Conversely, idle and fallow fields were increased as a result of farm abandonment. Although these programs helped farmers to recover and provided numerous soil conservation practices, they paid no attention diverse farming and crop rotation practices, being mainly mostly focused on monoculture practices.

The acreage of idle and fallow lands declined dramatically as the United States entered World War II and harvested cropland began to increase again to support the military and nation. Most of the areas devoted to cotton and corn production were replaced with soybean and rice. In order to accelerate the production, particularly

soybean, more herbicides and insecticides were implemented during that period. Meanwhile, mechanization was intensified tremendously due to labor shortages and financial improvements of farmers that caused significant enlargement in the farm sizes.

Dramatic changes were noted in American agriculture at the conclusion of World War II. Numerous abandoned agricultural farms and marginal land which had been left idle during the 1930s and for a period after the war were replanted to forest by the Soil Bank Program and the acreage of forestland increased across the United States dramatically between 1952 and 1963. However, this increasing trend was reversed by the early 1960s and the areas reserved for timberland production were cleared for a second time for cultivation, particularly soybean production. Significant increases were observed in the acreages of rice, soybean and cotton during the 1970s, particularly in the lower Coastal Plains and Delta Region due to increased irrigation projects.

Severe drought occurred in the late 1970s and early 1980s diminishing crop production all over the world that brought about significant increases in crop production in the United States between 1972 and 1981. However, overproduction became a major problem in the late 1980s as a result of reduced crop exports that resulted in reduction in the acreage of total cropland. CRP, a long-term conservation program, was initiated in 1985 to reduce the acreage of cultivated areas and withdraw the highly erodible agricultural lands out of production.

The land use activities humans practiced from colonial times to the present resulted in dramatic declines in NBW abundance as well as other game species. NBW basically requires agricultural crops, pastureland and woodlands. However, excess of one land use type over the others causes reductions in the habitat quality and quantity.

Intensive monoculture practices across the nation associated with intensive mechanization and chemical fertilizer corresponded with a diminished NBW habitat.

Small farms with diverse rotational cropping pattern were consolidated into larger units that eliminated weedy patches, thickets, hedges and fencerows, which previously provided feeding, nesting and protective cover for NBW. These modifications in the farms along with intensive cultivation meant that little food and cover were left for these species.

Some increases were noted in the NBW abundance for a short time period, particularly during the years of the Great Depression and Dust Bowl due to marginal land and farm abandonment. Although these abandoned areas may have created favorable habitats for NBW for a while, the species began to decline again as secondary succession took place in the fields. Similarly, young pine plantation stands furnish abundant food and nesting cover for NBW. However, as they densely stocked stands mature and canopies close, the habitat quality become unfavorable for NBW.

In summary, broad scale habitat deterioration and loss associated with intensive monoculture practices in agriculture and forestry are likely to be among the major causes of range wide decline in NBW abundance.

CHAPTER IV

RANGE CONTRACTION DURING SEVERE DROUGHT ALONG THE WESTERN EDGE OF THE NORTHERN BOBWHITE RANGE

INTRODUCTION

The fluctuations in the abundance of game species are often indicators of environmental changes. Weather is considered one of the significant factors affecting trends of northern bobwhite (*Colinus virginianus*, NBW) abundance (Edminister 1954, Klimstra 1982, Guthery 2000), which is susceptible to the impacts of extreme weather events such as drought, heat waves, floods and blizzards (Errington 1945, Roseberry 1964, Guthery et al. 2000b). Like many other animal species, NBW responds to weather conditions by increase or decrease in their abundance (Rosene 1969).

Weather conditions, both short-term and long-term (Schemnitz 1993, Bridges et al. 2001), may draw up the boundaries of the geographic distribution as well as their local abundance of NBW (Roseberry and Klimstra 1984). High habitat quality and availability (Johnsgard 1973, Goodwin and Hungerford 1977, Brennan 1991) may not attract and hold abundant NBW unless weather is favorable (Giuliano and Lutz 1993).

Many studies examined the relationship between NBW abundance and weather variables (Lehmann 1946, Guthery et al. 1988, Rice et al. 1993, Bridges et al. 2001, Hernandez et al. 2002). NBW is subject to dramatic fluctuations in response to drought as well as other climatic conditions across their range. Stoddard (1931) and Rosene (1969) speculated that severe drought could increase the mortality in NBW. NBW requires moisture during the incubation and recruitment period (Durell 1957, Speake and

Haugen 1960). An extreme drought that takes place during this period is most likely result in the fatality of the embryo (Edminster, 1954). In their experimental studies, Giuliano et al. (1995) found that water deprivation associated with severe drought might reduce both female and male NBW reproductive function.

The semi-arid Great Plains region of the United States, at the western end of the NBW range, has characteristically irregular pattern of precipitation and frequent drought. The prolonged drought in the 1930s in southwestern Great Plains region, combined with high temperatures and strong wind storms, created the Dust Bowl that was one of the worst environmental disasters of American history (Warrick et al. 1975, Cunfer 2001). The Dust Bowl was not only the result of bad weather but also human activities that substantially increased the vulnerability of the area to the drought (Hargreaves 1976). Poor dryland farming and grazing practices were used by settlers who were used to cultivate in more humid regions of the United States (Fite 1966, Bonnifield 1979). Extensive cultivation of marginal lands and abandonment of soil conservation practices occurred partially due to the legacy of agricultural policy of the World War I era (Hurt 1994), the development of new technology and crop varieties (Hurt 1994, Cochrane 1993), and the difficult economic condition during the Great Depression in the late 1920s. As a result, soil was eroded and blown away as drought and strong winds hit the region (Bonnifield 1979, Hurt 1994, 2002). The drought returned the Great Plains again in the 1950s causing overwhelming and widespread impacts (Warrick 1980, Wilhite 2003), particularly between 1952 and 1956 (Bark 1978). This drought affected much larger area of the Great Plains than the 1930s drought, although the conservation

practices that many farmers applied during the intervening period and better economic situation lessened to a degree the severity of the drought (Bark 1978, Hurt 1981; 1994).

In addition to the impact on agriculture and other aspects of the economy, these droughts had significant impacts on the NBW in the Great Plains region (Errington 1935, Jackson 1962). The influences of drought on quail species in these semiarid regions were well documented (Campbell et al. 1973, Giuliano and Lutz 1993, Bridges et al. 2001). Considerable amount of work was done on the influences of water restrictions and drought on NBW's reproduction success (Guthery et al. 1988, Koerth and Guthery 1991, Giuliano et al. 1999), the effects of rainfall on NBW and scale quail abundance (Giuliano and Lutz 1993), and the effects of drought on habitat changes (Rollins 2002).

It is a common conception that the NBW range may contract during years of severe drought along the dryer western edge of the range where NBW population may be reduced to very low density due to die out, or possibly migration. Although NBW is generally considered sedentary (Brennan 1999), Schorger (1946) and Bolgiano (2000) advocated that NBW could migrate when conditions compel them to. Edminster (1954) hypothesized that extreme weather conditions such as drought or severe winters may reduce an entire NBW population and force them to migrate hundreds of miles to another place where they can survive.

The objective of this study was to examine spatial pattern of NBW abundance in the Great Plains before, during, and after the severe drought of the 1950s based on the Christmas Bird Count (CBC) data, and test the hypothesis that the range of NBW contracted along its western edge during the severe drought period and recovered after

the drought. The effect of the 1030s drought was not examined because the lack of sufficient CBC circles in the western Great Plains during that time period.

METHODS

The study area included the Great Plains region, the western boundary of which roughly corresponded to the western edge of the NBW range. For the purpose of the study, this region was divided into 13 longitudinal zones each was 100 km in width. These zones were named by their corresponding longitudes, ranging from 105.74, 104.44, ... to 91.24 as one traveled from west to east. An additional 100-km zone to the east of the Great Plains region (longitude 90.04) was added to the study area in order to facilitate the examination of the shift in NBW abundance eastwards beyond the Great Plains during drought periods.

The degree of drought in the Great Plains region was measured using average Palmer Modified Drought Indices (PMDI) for the region. Data for monthly PMDI for individual zones (multiple zones in each State) that fall within the Great Plains region were acquired from the National Oceanic and Atmospheric Administration's (NOAA) National Climate Data Center (NCDA), and used to generate annual average PMDI values for the Great Plains region for 1948 through 1960. The values for PMDI range from ≥ 4.0 (extreme wetness) to ≤ -4.0 (extreme drought) with near normal values ranging from about 1.5 to -1.5.

Christmas Bird Count (CBC) data were used to evaluate the relative abundance of NBW in the Great Plains region. The CBC data were processed using SAS (Version 8.01; SAS Institute Inc, Cary, NC) and standardized by dividing counts by party miles as

observer effort. Average values of the standardized NBW count were calculated for each of the thirteen longitudinal zones for 1948 through 1960 by based on the values of all the circles felt within each longitudinal zone.

A 3-D surface plot, with year and longitudinal zone as the X and Y-axis and average count as the Z-axis, was generated to show the longitudinal pattern of NBW abundance during years before, during and after the major drought in the 1950s. Chi-square (goodness of fit) tests were performed to test the differences between the longitudinal frequency distribution during the drought years and those during the years before and after the drought.

A geographic information systems (GIS) database of the standardized count for NBW was developed. To facilitate the interpretation of the pattern in changes of NBW abundance, the standardized counts for each year were spatially interpolated over the species range to generate maps of relative abundance (grids with 2-km cell size) using inverse distance weighted (IDW) method in ArcView GIS (ESRI, 1998).

RESULTS

The average values of PMDI over the Great Plains showed that a prolonged drought period occurred in the 1950s (Fig. 4.1). The drought was most severe from 1953 to 1956. It was also severe in 1952; although the average PMDI value was not as negative as those for 1953 through 1956, the variance in PMDI was very large ($cv=383\%$) suggesting severe drought in many parts of the region. The overall abundance of NBW was dramatically affected by this drought. The average standardized count of NBW over the Great Plains region dropped to substantially lower values during 1952-1956

compared to those in the years before and after this period (Fig. 4.1). There was a significant correlation between the PMDI and NBW abundance in the region ($r=0.84$, $p<0.001$).

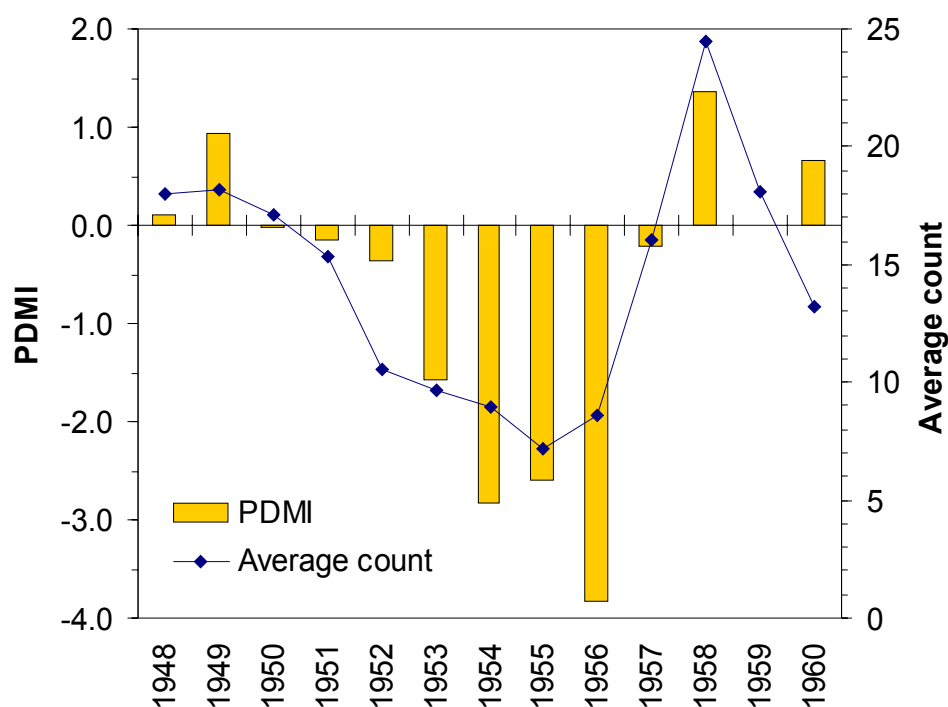


Fig. 4.1. Average Palmer Modified Drought Indices (PMDI) values and relative abundance of northern bobwhite (average standardized count based on the Christmas Bird Count data) for the Great Plains region from 1948 to 1960

The 3-D surface plot of the longitudinal distribution of the relative abundance of NBW in the Great Plains region (Fig. 4.2) showed relatively high, but spatially dynamic, abundance of NBW in 1948-1951. It was followed by a substantial reduction across the Great Plains region during the severe drought in 1952-1956, while the abundance remained relatively high in the areas immediately east of the region. NBW abundance

recovered in the years following the severe drought (1957-1960), but not completely in the western portion of the Great Plains.

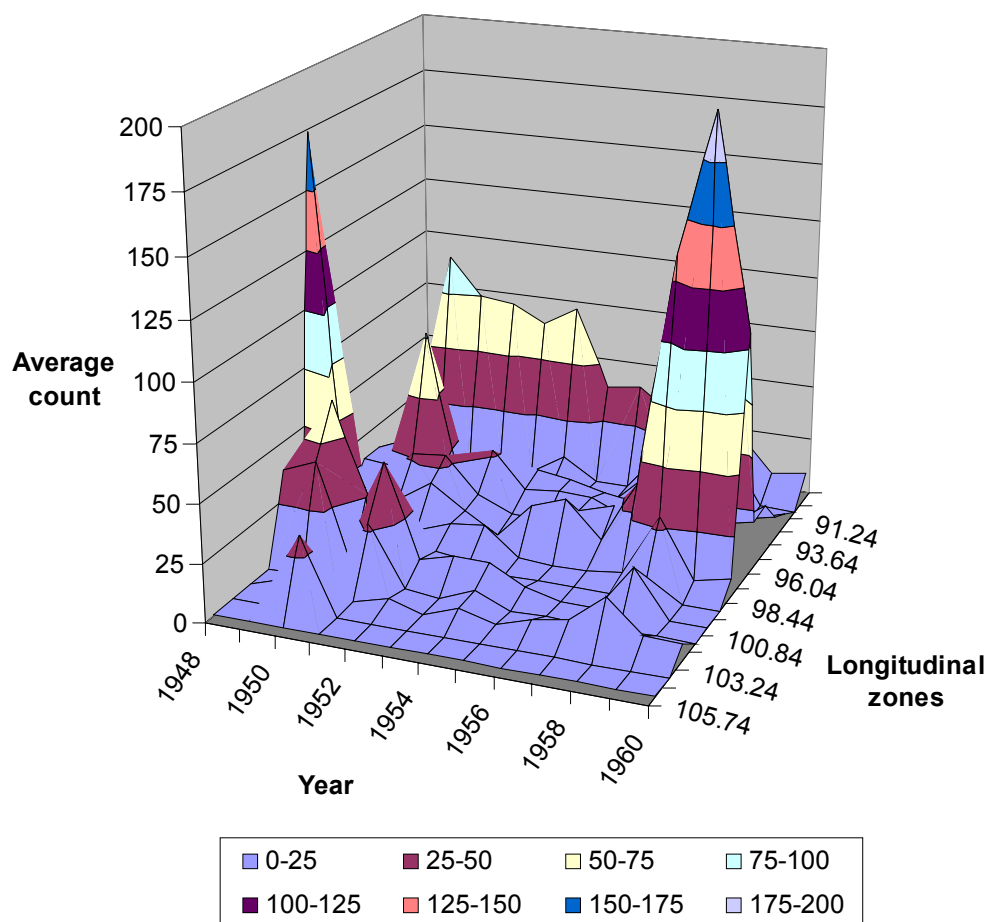


Fig. 4.2. A 3-D surface plot showing the pattern of longitudinal distribution of the relative abundance of NBW (average standardized count based on the Christmas Bird Count data) in the Great Plains region from 1948 to 1960

This pattern was shown clearly in the comparison of the frequency distribution of the average abundance of NBW along longitudinal zones between the pre-drought (1948-1951), drought (1952-1956), and post-drought (1957-1960) periods (Fig. 4.3).

Chi-square goodness-of-fit tests showed significant difference ($p < 0.001$) between the frequency distribution of the drought period and either the pre-drought or post-drought period. The frequency distributions of the pre-drought and post-drought periods were also significantly different based on a Chi-square test ($p < 0.001$); it reflected the substantial difference of the post-drought longitudinal pattern from the pre-drought pattern, with a large peak in the middle of the region but still low abundance in the western portion of the range.

The spatially interpolated maps of relative abundance of NBW (Fig. 4.4) showed the relatively high abundance of NBW in 1948-1951, extending to the western edge of the range extending to the western edge. Although there was considerable year-to-year variation, the areas of high abundance tend to be in Nebraska, Kansas, and Oklahoma. During the years of severe drought (1952-1956), the abundance level of NBW was low in most of the region, especially in areas near the edge of the range where the abundance level was very low (≤ 1). The abundance of NBW recovered during the post-drought years (1957-1960), with an especially abundant year in 1958. The distribution of high-abundance areas varied from year to year and in addition to Nebraska, Kansas, and Oklahoma, south Texas became a consistent high-abundance area. The abundance of NBW in areas near the western edge of the range, however, remained low during this period except for 1958.

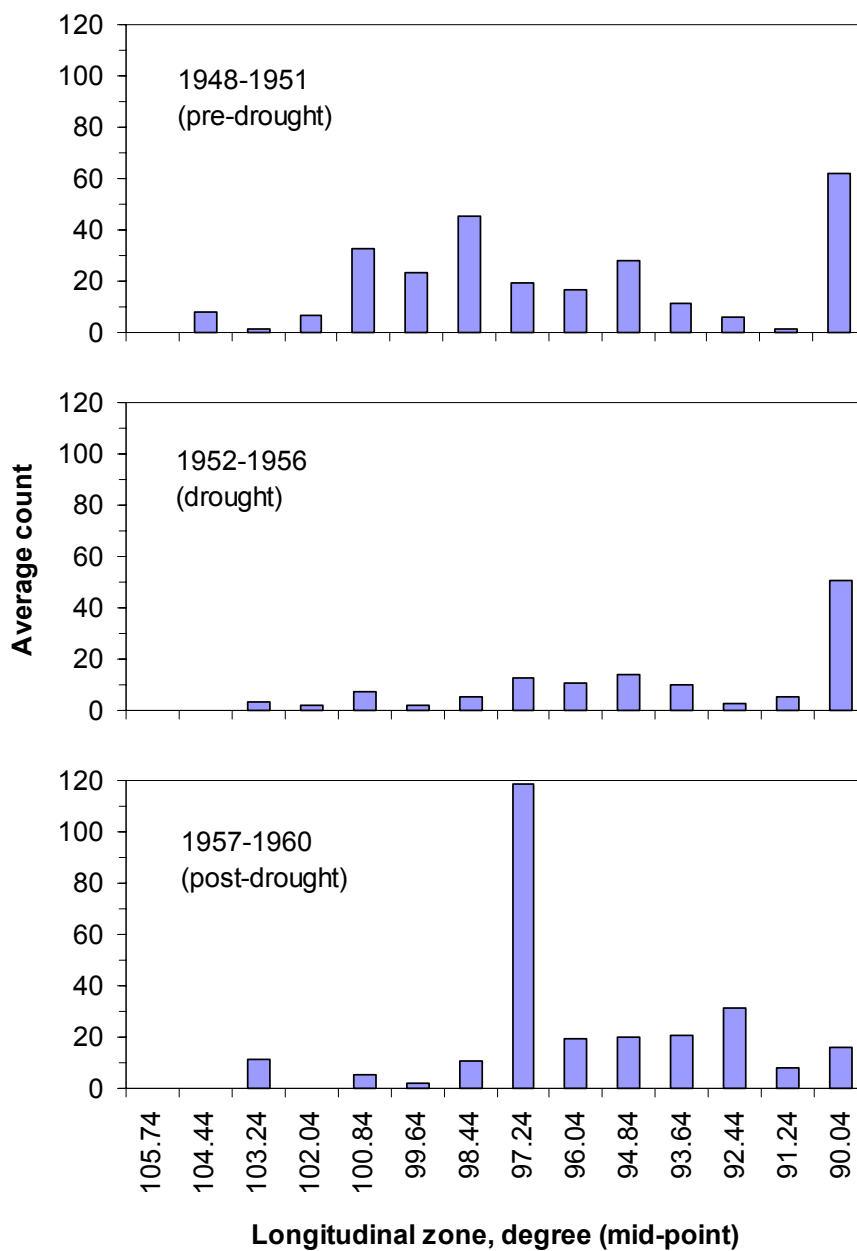


Fig. 4.3. Frequency distribution of the average abundance of NBW along longitudinal zones in the Great Plains region between the pre-drought (1948-1951), drought (1952-1956), and post-drought (1957-1960) periods. The last zone (90.04) was outside (east) of the Great Plains region

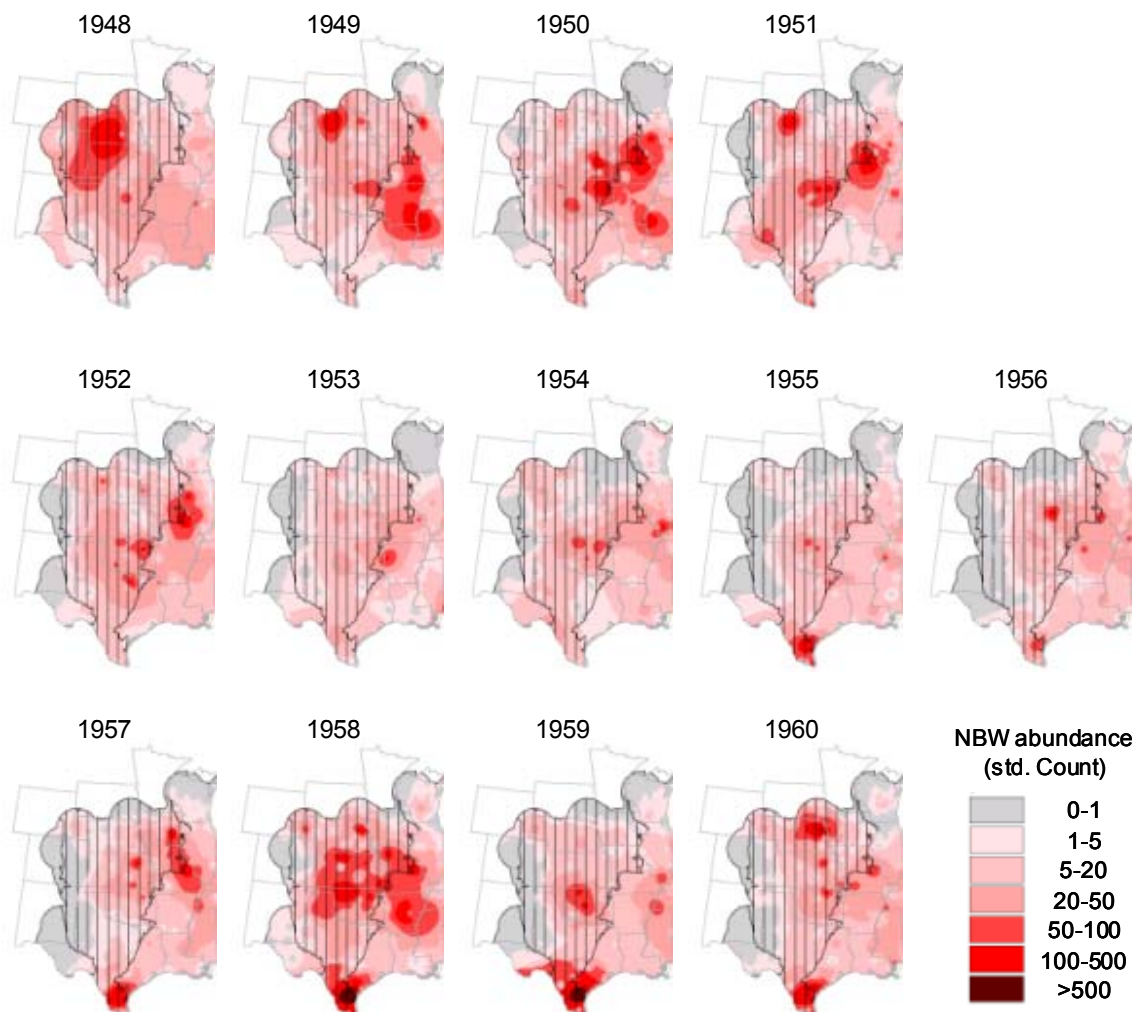


Fig. 4.4. Interpolated maps of relative abundance of northern bobwhite (standardized count based on the Christmas Bird Count data) over its range in 1948-1960. The black lines outline the Great Plains region and 100 km-wide longitudinal zones within the region

DISCUSSION

Drought is certainly one of the major environmental phenomena since the beginning of human history. The Great Plains experienced numerous significant droughts during the 20th century. In fact, this situation did not happen only in the last century. Historical records indicate that multi-year drought occurred in the Great Plains once or twice a century over the last 400 years (Woodhouse and Overpeck 1998). Among them, the 1930s and 1950s were the most widespread and enduring ones (Bark 1978, Walker et al. 1991, Schubert et al 2004).

The drought's greatest impact is mostly considered to be agricultural. However, the lack of precipitation affected many wildlife and plant species (Wilhite 2003). For instance, several successive drought years in the Great Plains lowers the productivity of the ducks that result in declines in continental species abundance (Hansen and McKnight 1964, Crissey 1969).

The Great Plains suffered severe drought in the 1950s (Fig. 4.1), as cited in the literature (Bark 1978, Chang and Smith 2001, Schubert et al. 2004). Severe declines were also experienced in the NBW abundance in this region during this period (Fig. 4.1). The significant correlation between the overall PMDI and NBW abundance ($r=0.84$, $p<0.001$) in the Great Plains region in this period suggested that NBW was especially sensitive to drought in this semi-arid region, which was supported by sub-regional studies (Jackson 1969) and corroborated with the observed strong correlation between NBW abundance and rainfall (Brennan 1991, Giuliano and Lutz 1993).

Jackson (1969) stated that NBW reproduction generally drops throughout the Rolling Plains during the periodically occurring drought years. Although significant

fluctuations were observed in the number of NBW in the Rolling Plains from 1951 to 1958, the most severe reduction was noted in 1952 (Jackson 1969). Similarly, NBW numbers were curtailed in the Canelo Pasture in 1951 and 1952 as a result of severe drought occurring in that period (Lehmann 1984).

The results of this study showed that longitudinal pattern in the distribution of NBW abundance in the Great Plains region exhibited significant shifts from before to during and after the drought of the 1950s (Figs. 4.2, 4.3). NBW abundance in the Great Plains region decreased significantly from the period before the drought to the drought period while the NBW abundance in the area just east of the region remained at a higher level. The NBW abundance in the areas of the Great Plains near the western edge of the NBW range dropped to a very low level (≤ 1 standardized count) during the drought period (Fig. 4.4), although with some year-to-year variation, and practically resulted in an eastwards contraction of the NBW range.

This contraction and shift of NBW abundance eastwards might have two possible mechanisms. One was that the increased mortality and decreased reproduction caused by the drought had led to local population reduction or extinction. Another possible mechanism and not one mutually exclusive with the first one, however, was the possible migration of NBW between regions in extreme circumstances such as drought and severe winter (Schorger 1946, Edminister 1954, Bolgiano 2000).

NBW is known as the most sedentary one among all quail species (Stoddard 1931, Johnsgard 1973). Most flights are made over relatively short distances and no seasonal movements are generally performed (Stoddard 1931, Rosene 1969, Brennan 1999). Rosene (1969) and Brennan (1999) both argued that migration process is unusual

for these species and seasonal movements between low elevations during the winter seasons and high elevations during the breeding seasons should be considered as dispersal rather than migration.

Leopold (1931) and Bolgiano (2000), however, reported that early settlers had seen huge flocks of NBW migrating from northern Ohio to the Mississippi River at various locations in Ohio, Indiana, and Illinois and both sides of the Mississippi River between Iowa and Illinois. Similarly, Schoerger (1946:89) argued that “there is little doubt that the habit of quail to emigrate or irrupt, when a certain density of population was attained, was a powerful factor in producing the huge numbers that existed in Wisconsin in the decade prior to 1854”.

NBW abundance in the Great Plains region recovered after the severe drought of 1952-56, but the longitudinal pattern of the post-drought period was significantly different from that of the pre-drought period (Figs. 4.1, 4.2). The areas near the western edge of the range that were vacated during the contraction still had few NBW, except for the boom year of 1958, and a new and persistent area of high NBW abundance developed in south Texas.

These persistent changes in the spatial pattern of NBW abundance suggest that severe drought may not only cause short-term changes in regional patterns of NBW abundance and contraction of the range, but also can induce long-term and large-scale changes in the pattern of spatial distribution of NBW abundance. It would be interesting to explore what and how interactions among the spatio-temporal patterns of climate fluctuation, land use change, and possibly migration of NBW influence the dynamics of the spatial distribution of NBW abundance in the semi-arid Great Plains region.

In summary, the drought of the 1950s led to significant changes in the longitudinal pattern of NBW abundance in the Great Plains region and resulted in substantially reduced NBW abundance across the region and a contraction of the NBW range at its western edge. NBW abundance in the Great Plains recovered in the post-drought period but exhibited a longitudinal pattern that was significantly different from that of the pre-drought period, with incomplete recovery along the western edge and development of new areas of high NBW abundance.

These findings suggest that severe drought can not only cause short-term changes in regional distribution of NBW and range contraction, but can also induce long-lasting, large-scale changes in the pattern of spatial distribution of NBW abundance.

CHAPTER V

SUMMARY

RANGE-WIDE PATTERNS AND DYNAMICS IN NORTHERN BOBWHITE ABUNDANCE, 1920-1990

It is well known that a broad scale, long-term decline in northern bobwhite (*Colinus virginianus*, NBW) abundance has occurred in the United States for decades. However, it is unclear when it began, exactly where it occurred, or whether the causes are the same under most circumstances. The results of spatial pattern and temporal dynamic analysis of NBW abundance based on the Christmas Bird Count (CBC) data from 1920 to 1990 indicated that a long-term decline occurred in the species abundance at least since the 1920s.

Although an obvious decline was observed over a 70-year period in most parts of the species' geographical range, the abundance distribution and trends were spatially heterogeneous. In the 1920s, NBW was abundant in most parts of their range. However, it exhibited a gradual decline in the 1930s and 40s. Severe reductions in the abundance were noted between 1940 and 1950.

The overall abundance of NBW remained relatively stable from 1950 to 1970, and the spatial distribution of abundance varied in each decade in many parts of the range. Another widespread decline in NBW abundance occurred during the 1980s, in almost every part of their range except some regions of the Texas and Oklahoma panhandles. Also, their decline was particularly felt in the northern and eastern portions of the species range.

Changes in weather pattern and habitat loss resulting from changes in land use are considered the most likely causes of the broad scale declines in NBW. The weather pattern is an important factor that regulates the abundance of most game species, including NBW. NBW is susceptible to winter and summer catastrophes such as blizzards, drought, heat waves, etc.

Winter losses occur particularly in the northern parts of the range and they are usually associated with unusually long snow covers and freezing temperatures, whereas summer losses take place mostly in the southern portions of the range in the form of excessive drought or rain. Prolonged deep snow covers and below normal temperatures result in dramatic reduction in NBW abundance. Similarly, excessive drought or rain might decimate drastically NBW abundance. Drought depresses the NBW reproduction significantly, while large amount of rain may wash away NBW nests.

The primary reason for the decline in NBW abundance throughout their range is generally related to dramatic habitat loss due to changes in land use. Advanced natural succession, clean farming practices, intensive monoculture practices in agriculture and forestry have resulted in the reduction of NBW numbers throughout their range for decades.

In agriculture, the replacement of diverse rotational farming practices, associated with row crops, small grains, hay and vegetables, with intensive monoculture production of corn, cotton, rice and soybean gave rise to the decline in NBW abundance. In forestry, densely planted pine plantations resulted in advanced succession that eliminated the suitable habitat that once provided the feeding, nesting, brood rearing and protective environment for NBW. Intensive mechanization and clean farming also caused reduction

in the abundance of NBW by removing thousands of miles of weedy ditches, fencerows and small fields that previously provided the best habitat for these species.

HISTORICAL LAND USE PATTERN AND DYNAMICS ACROSS NORTHERN BOBWHITE RANGE

It is a common belief that habitat loss and degradation due to the changes in land use are primarily responsible for the long-term wide-range declines in NBW abundance over decades. This study showed there had been tremendous changes in agricultural land use in the last century, changes which were attributed to federal policies, socio-economic events and natural disasters.

Historically, high NBW abundance was created accidentally by the European colonizers' practice of developing low intensity agriculture, associated with small field sizes, diverse row cropping patterns, grass, fallow and woody vegetation. During pre-industrial times the creation of diverse land use patterns favored a growth in NBW abundance. However, this trend was reversed, particularly at the beginning the 20th century. After World War I the nature of American agriculture began to change dramatically. There were many technical advances, political incentives and market forces, which led farmers to change many of their practices.

The most notable change was the introduction of mechanization and artificial fertilization into farming practices. These innovations reduced the demand both for draft animals and fields to sustain them. Thus, more land was plowed under and put to the production of cash crops. Additionally, lands that had had marginal value, due to their inaccessibility or topography could be cultivated. Federal policies encouraged farmers to

move towards a market economy and away from the self-sustaining practices. Europe's turmoil also provided farmers with a steady and dependable market at that time.

With Europe in distress, due to the war, federal policies promoting monoculture, and the seemingly easy access to additional land, American farms felt confident and began to invest in the new technologies needed to mechanize and increase the size of their farms. However, after the end of the World War I, food prices dropped significantly, as the European products began to hit the world market. The loss of the export market coupled with the tremendous increase in the local production sent crop prices plummeting. In response to this, many farmers abandoned their lands, and thus allowed their fields to go fallow. This shift in land use, allowed the NBW to flourish once more, though only for a short time. As secondary succession took over the fallow fields, the quality and quantity of habitat decreased for NBW.

This loss of habitat was followed by even greater destruction to their environment as the American farmers began to recover from their own devastation. The farmers faced a severe crisis in America as they were hit by the hardships brought by the Great Depression and the adverse effects of years of poor farming practices and prolonged drought, which resulted in the Dust Bowl. To address some of these issues, the federal government began to push through legislation such as the Agricultural Adjustment Act and the Soil Conservation and Domestic Allotment Act, which aimed to reduce the production of excess cash crops and promote the cultivation of nitrogen and soil fixing crops. Though these were some of the first efforts of federal policy to address the environmental impact of land use practices on the environment, the policies were single issue oriented and were not accompanied by a systemic analysis of their impact.

These policies addressed many of the problems they had set out to fix, but resulted in further deteriorating the NBW habitat, by promoting monoculture productions rather than diversified farming and crop rotation practices.

With the dawning of World War II, many of the market forces, which had ultimately lead to the farmers' demise a few decades earlier, were recreated. The American farmers, once again, responded to market forces, but in doing so, continued to alter their culture and land use practices. Farmers followed the same trends previously established, which lead to greater mechanization, consolidation of farms, and the overall industrialization of food production. As more land was cultivated, and more artificial fertilizers used, federal policies supported a narrowing of crop diversity resulting in monoculture production and the increased use of mechanization. The larger field sizes and the increased use of machinery in the harvesting process depleted the available NBW habitat, thus bringing down their overall numbers.

As farm production became more efficient, through the use of mechanization and the ability to reduce crop waste, NBW abundance decreased. Federal policies and market responses tended to be narrowly focused on a single end result, which was an increase in crop yield. This tunnel vision has lead farmers away from sustainable land use practices and simultaneously destroyed the ecological balance needed to sustain and nurture indigenous wildlife, even those as common and wide spread as the NBW.

EFFECT OF DROUGHT ON NORTHERN BOBWHITE IN THE GREAT PLAINS AND THE RANGE CONTRACTION

Using the Christmas Bird Count (CBC) and the Palmer Modified Drought Index (PDMI) data, the affects of the 1950s drought in the Great Plains on NBW abundance were examined, and the hypothesis that the NBW range contracted along its western edge during the drought period and rebounded once again afterwards was tested. In order to examine the fluctuations in NBW abundance during the drought period, a 100-km zone East of the Great Plains was added to the study.

The results of this study showed that the Great Plains experienced an extreme drought between 1952 and 1956 as cited in the literature. An inverse relationship ($r=0.84$, $p<0.001$) was observed between NBW abundance and PDMI, and the number of NBWs is reduced as the drought hit the region. During the pre-drought period (1948-1951), NBW had greater abundance but their spatial distribution varied from year to year. A significant decline was noted in NBW abundance during the drought period (1952–1956), particularly in the western parts of the region. The downward trends were reversed as the rains returned to the region once more. The longitudinal distribution of NBW abundance during the drought period was significantly different ($p<0.001$) from those during pre-drought and post-drought periods. The longitudinal distribution of NBW abundance during pre-drought period also differed significantly ($p<0.001$) from that of post-drought period. NBW abundance did not recover completely along the western edge of the NBW range and a new population center was developed in south Texas. These findings suggest that, in addition to the broad short-term decline in NBW abundance during the

drought, the severe drought had lasting effects on the spatial distribution of NBW in the years after the drought.

FUTURE DIRECTIONS IN ECOLOGICAL CONSERVATION - RESEARCH AND PLANNING

The landscape of the United States has been altered dramatically since the first European settlers arrived in excess of four centuries ago. Hundreds of thousands of acres of hardwood and pine forests and large prairies greeted these early explorers, and retained a great diversity of wildlife species, including NBW. Congress recognized the public lands as a national asset, and used it as a recruiting method, allocating billions of acres of public domain to be given to individuals either freely or sold for very low prices for the promotion of Western settlements.

As settlements moved westward, competition for land and water intensified and settlers started to change the natural landscape drastically. Vast areas of land and forest were cleared to create homes, agricultural lands, pastures, roads and towns, which broke up the continuity of a number of natural systems. Moreover, land was put to uses that were not sustainable over the long-term, and insufficient thought was given to future needs.

The rapidly growing population, combined with industrial markets, created a steadily increasing demand for farm products. The adoption of science, technology, transportation, and imported livestock breeds resulted in rapid changes in industry.

As a result of all these land-altering events, a large number of habitats in the United States have become highly fragmented. The result is that many ecosystems have become

isolated into smaller pieces and often no longer function in an ecologically sound manner for many wildlife species, including the NBW.

Mankind obviously cannot survive without agriculture. However, exploiting the land or using it carelessly, not only affects the land, but also the species dependent on it for survival. The circumstances and problems we face today reflect and result from American actions in the past. From our past actions, we can see that the human interface with nature was not considered part of a systemic whole and the compartmentalization of our behavior has led to enduring problems.

The magnitude of species decline and loss is overwhelming and perhaps the most important issue at the present time. The number of endangered or threatened species on the Endangered Species Act list continues to rise. NBW can be one of them, unless considerable research and appropriate management efforts are made.

The depressing point is that our globe is increasingly becoming empty in terms of the number and diversity of species. Species extinction results in countless lost opportunities for human enhancement. Moreover, the loss of each species affects our lives significantly in many ways. This affect is described by Capra (1996), which links all living organisms together and creates a complex system of interdependent relationships between society and environment. In this complex relationship, the loss of each single species influences other species, which in turn affects us.

As members of this community, we should find certain obligations to protect the habitats and ecosystems of other life forms as well as our own. Aldo Leopold (1949:204) expressed such an ethic in his discussion about the need to move from an ethical position

of conqueror of the environment, to being a “plain citizenship” of it. According to Leopold we are all equal members of a complex and interconnected network of life.

As environmental awareness grows around the world, people are learning that the diversity of species and the habitats needed to support them are necessary for maintaining the ecological health of the earth. At the same time, however, the pressure for human settlement and economic gains are also growing, causing frequent conflicts between the forces of development and conservation.

This study adds to the growing body of works which highlight the negative impact humans have had on the environment, and simultaneously serves as a clarion call for a reassessment of our relationship with the earth and other beings. Although these thoughts are not new, and now even seem trite, the reality is that little has been effectively done to change the American consciousness and our behavior towards the land. To effect behavioral change, there must be a cultural change on a community level. This must be facilitated through both grassroots and educational efforts as well as through policy initiatives.

Preserving biodiversity and conservation of species has become a major concern for planners as threats to species loss and extinction have increased due to urbanization and land use changes. There are many different types of models proposed for the improvement of the human interface with nature. These range from ideas such as cluster development, adaptive management, green development, sustainable development, and incentive programs. Although, it is not currently known which idea or program works for certain species, all of these are steps in the right direction, and need to be continued.

This study emphasizes the need for the development of national policies to promote ecological systemic thinking. Up to now, the only national efforts, in this regard, are those created through the Environmental Protection Act and the Endangered Species Act, which do not look at land use patterns, and have also been stripped of almost all of the little enforcement power they once had. These programs have been largely reactive, single-issue driven, piecemeal in focus, and fragmented in geographical scope. They have attempted to provide local solutions for national problems and have not satisfactorily addressed the core issues relating to the human and land use interface.

Habitat loss and species degradation are not a localized problem, which would require a localized solution. The loss of NBW species is just an example of our past errors, caused by national policies and a culture of limitless resources, which has led to problems that also demand national solutions and cannot be solved simply by individual actions. The human interface with the landscape is a complex one which encompasses many aspects, from the economy, to land use and natural wildlife.

To make a lasting change in this relationship we need to address our role in the larger system and create more sustainable behavioral patterns. This means attacking the problem through better policies, planning and education. New and courageous plans are needed, particularly large-scale conservation strategies that provide a guide and framework for planning and actions at fine scale. In addition, new approaches should be taken including acquiring funding, providing creative incentives for conservation on private lands, visualizing new roles for urban areas in restoring and conserving species and habitats, and giving greater attention to species conservation actions in planning curricula.

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